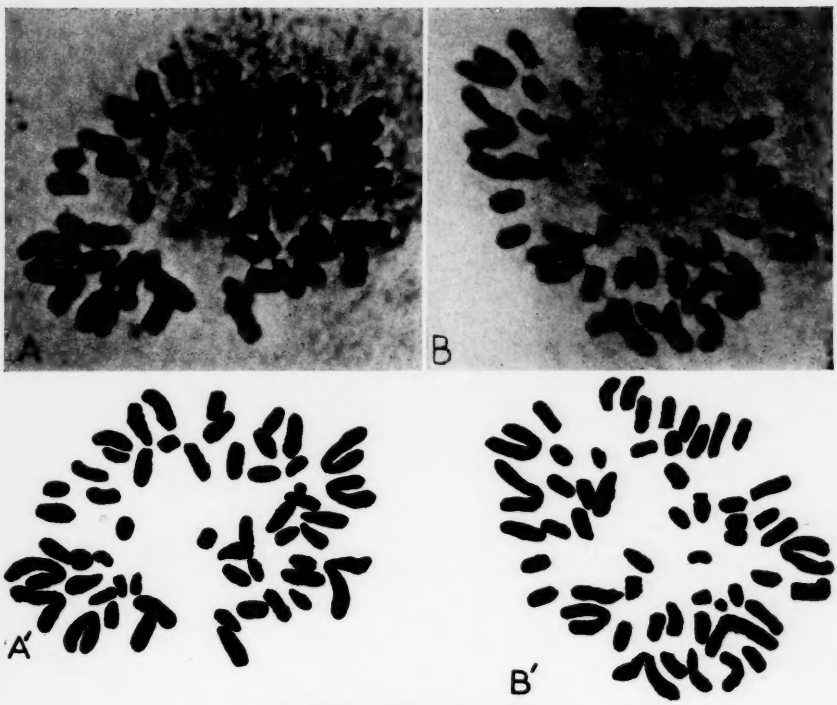
The Journal of HEREDITY



SHEEP CHROMOSOMES

(SEE PAGE 261)

THE PALOMINO HORSE

GENETICS AND HUMAN RACES

A SEX-LINKED FINGERPRINT PATTERN

AN INDUSTRY BASED ON A POLYPLOID RACE

PROTOZOA IN BIOLOGICAL RESEARCH

THE MECHANISM OF TWINNING

A TETRAPLOID SNAPDRAGON

VOLUME 32 AUGUST, 1941 NUMBER 8

The American Genetic Association

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The

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CONTENTS

THE CONCEPT OF RACE IN THE HUMAN SPECIES IN THE LIGHT OF GENETICS
By M. F. Ashley Montagu 243

GALAX: THE GENUS AND ITS CHROMOSOMES
By J. T. Baldwin 249

THE INHERITANCE OF EQUINE COAT COLOR
By G. W. Salisbury and J. W. Britton 255

THE CHROMOSOME COMPLEX OF DOMESTIC SHEEP
By R. O. Berry 261

TWINNING IN CHICK EMBRYOS
By C. H. Waddington 268

THE INHERITANCE OF PARALYSED HIND LEGS, SCROTAL HERNIA AND ATRESIA ANI IN PIGS
By S. Berge 271

A SPONTANEOUS TETRAPLOID SNAPDRAGON
By Ronald Bamford and Fred B. Winkler 278

A SEX LINKED RECESSIVE FINGERPRINT PATTERN
By J. Frank Walker 279

POLYPLOID CASSAVA
By E. A. Graner 281

Notes and Reviews

RUSSIAN CONTRIBUTIONS TO THE 1939 GENETICS CONGRESS 248

SEX-RATIOS IN SHEEP TWINS 254

BIOLOGICAL RECLAMATION OF HOMO 260

HOW LONG WILL WEED SEEDS LIVE? 270

PROTOZOA IN BIOLOGICAL RESEARCH 275

THE TONGUE-TIED TWIN 288

FLESH AND BONE GENES IN THE FOWL 283

STUDENT SUBSCRIPTIONS

The **Journal** has obvious advantages as a supplementary text in genetics classes. Since genetics deals mainly with form and pattern differences in organisms the **Journal** offers an unexcelled introduction to current developments, which have an added interest and appeal on account of the large number of illustrations published.

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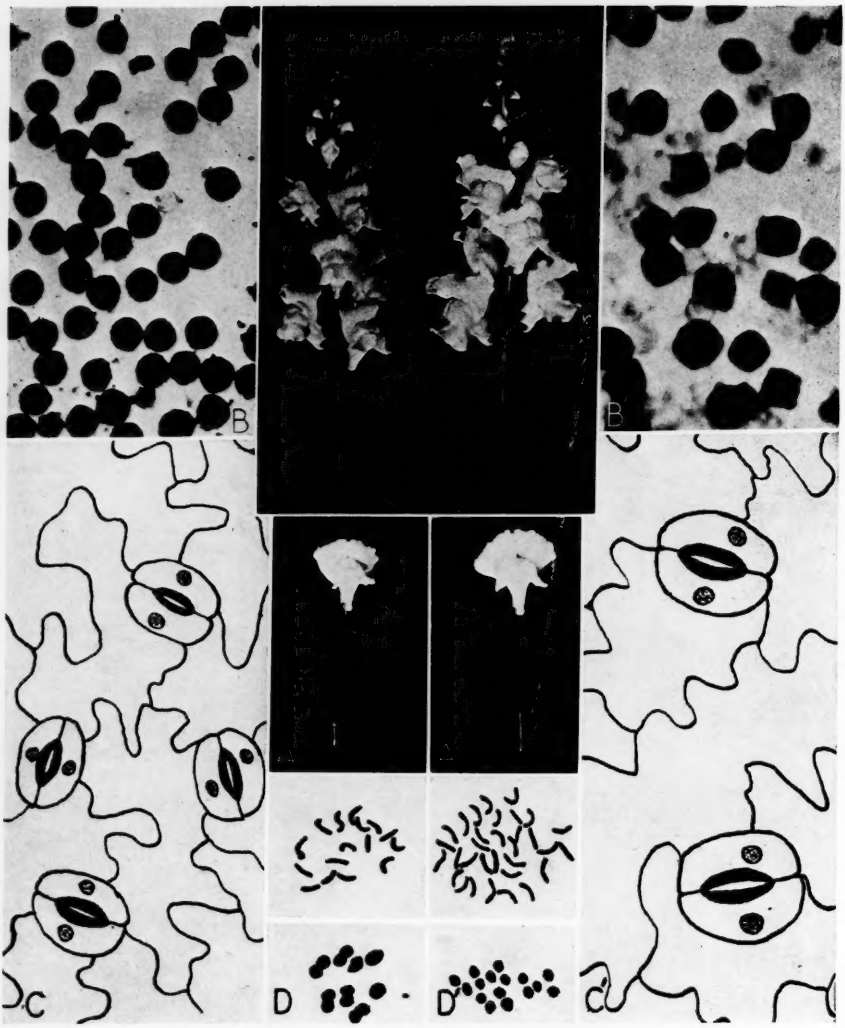


A SPONTANEOUS TETRAPLOID SNAPDRAGON

Frontispiece

(*See Page 278*)

The right half of this plate shows details of a tetraploid snapdragon which appeared spontaneously in the progeny of a cross between two commercial varieties. The tetraploid structures (*A'-D'*) are larger than the corresponding diploid structures (*A-D*). No treatment was given the plants, so the mechanism whereby the doubling of the chromosomes took place is not known. Magnification: Plants (*A-A'*) × .5; Pollen (*B-B'*) × 165; Stomata (*C-C'*) × 600; chromosomes (*D-D'*) × 1600.

THE CONCEPT OF RACE IN THE HUMAN SPECIES IN THE LIGHT OF GENETICS*

M. F. Ashley Montagu
Department of Anatomy, Hahnemann Medical College and Hospital, Philadelphia

IT is said that when the theory of evolution was first announced it was received by the wife of the Canon of Worcester Cathedral with the remark, "Descended from the apes! My dear, we will hope it is not true. But if it is, let us pray that it may not become generally known."

I rather feel that the attempt to deprive the anthropologist of his belief in race is a piece of cruelty akin to that which sought to deprive the Canon's wife of her belief in special creation. Indeed, the anthropological conception of race and the belief in special creation have much in common. The prevailing attitude of mind is illustrated by the remark of a colleague who, when I gave him an account of the paper I proposed to present at this meeting replied, somewhat like the Canon's wife, "My dear, I always thought that there was such a thing as race." I believe he had spoken more correctly had he said that he had always taken the idea for granted. Certainly, I had always taken the idea for granted, and I think all of us have done so. Indeed, the idea of race is one of the most fundamental, if not *the* most fundamental of the concepts with which the anthropologist has habitually worked. To question the validity of this fundamental concept upon which we were intellectually brought up as if it were an axiom, was something which simply never occurred to one. One doesn't question the axioms upon which one's science, and one's activity in it, are based,—at least, not usually. One simply takes them for granted.

But in science, as in life, it is a good practice, from time to time, to hang a question mark on the things one takes most for granted. In science such questioning is important because without it there is a very real danger that certain erroneous or arbitrary ideas which may originally have been used merely as a convenience, may become so fortified by technicality and so dignified by time that their original infirmities may be wholly concealed.

Early Views

Blumenbach, in 1775 and in later years, foresaw this danger with respect to the usage of the term "race," and warned that it was merely to be used as a convenience helpful to the memory and no more. Herder, who was the first philosopher to make extensive use of Blumenbach's work wrote, in 1784 in his *Ideen zur Philosophie Der Geschichte der Menschheit,* "I could wish the distinctions between the human species, that have been made from a laudable zeal for discriminating science, not carried beyond the due bounds. Some for instance have thought fit, to employ the term *races* for four or five divisions, originally made in consequence of country or complexion: but I see no reason for this appellation. Race refers to a difference of origin, which in this case does not exist, or in each of these countries, and under each of these complexions, comprises the most different races. . . . In short, there are neither four or five races, nor exclusive varieties, on this Earth. Complexions run into each other: forms follow the genetic character: and upon the whole, all are at last but shades of the same great picture, extending through all ages, and over all parts of the Earth. They belong not, therefore, so properly to systematic natural history, as to the physico-

*Lecture delivered before the American Association of Physical Anthropologists, Chicago, April 7, 1941.

geographical history of man." When the last word has come to be said upon this subject it will, I am convinced, be very much in the words of Blumenbach and Herder. Meanwhile I propose to make a step in this direction here by showing that the concept of race is nothing but a whited sepulchre, a conception which in the light of modern experimental genetics is utterly erroneous and meaningless, and that it should therefore be dropped from the vocabulary of the anthropologist, for it has done an infinite amount of harm and no good at all.

The development of the idea of race may be clearly traced from the scholastic naturalization of Aristotle's doctrine of the Predicables of Genus, Species, Difference, Property and Accident. From thence it may be directly traced to the early days of the Age of Enlightenment when Linnaeus, in 1735, took over the concepts of Class, Species and Genus from the theologians to serve him as systematic tools. The term race was actually first introduced into the literature of Natural History by Buffon who, in the year 1749, used it to describe six groups of man.

The term merely represented an extension of the Aristotelian conception of Species, that is to say, it was a subdivision of a species. Buffon recognized that all human beings belonged to a single species, as did Linnaeus, and he considered it merely *convenient,* and I emphasize the word convenient, as did Blumenbach after him, to distinguish between certain geographic groups of man. Thus, at the very outset the term was understood to be purely arbitrary and a simple convenience.

The Aristotelian conception of Species, the theological doctrine of special creation and the Natural History of the Age of Enlightenment, as represented particularly by Cuvier's brilliant conception of Unity of Type, namely the idea that animals can be grouped and classified upon the basis of assemblages of structural characters which, more or less, they have in common, these three conceptions fitted together extremely well and together yielded the idea of the Fixity of Species. An idea which, in spite of every indication to the contrary in the years which followed, was gradually extended to the concept of race.

The Darwinian contribution was to show that species were not as fixed as was formerly believed, and that under the action of Natural Selection one species might give rise to another, that all animal forms might change in this way. It is, however, important to remember that Darwin conceived of evolution as a process involving continuous materials which, without the operation of Natural Selection, would remain unchanged. Hence under the Darwinian conception of species it was still possible to think of species as relatively fixed and immutable, with the modification that under the slow action of Natural Selection they were capable of change. For the nineteenth century anthropologist, therefore, it was possible to think of race, not as Buffon or Blumenbach did in the eighteenth century as an arbitrary convenience in classification, but as Cuvier at the beginning of the nineteenth century had done for all animals, as groups which could be classified upon the basis of the fact that they possessed an aggregate of common physical characters, and as Darwin later postulated, as groups which varied only under the conditions of Natural Selection, but which otherwise remained unchanged.

This is essentially a scholastic conception of species with the one additive fundamental difference that a species is considered to be no longer fixed and immutable. As far as the anthropological conception of race is concerned, the anthropologist who can afford to pass by the findings of experimental genetics, still thinks of race as the scholastics thought of species, as a knowable fixed whole the essence of which could be defined *per genus, propria et differentia.*

In fact, what the anthropologist has done has been to take a very crude eighteenth century notion which was originally offered as no more than an arbitrary convenience, and having erected a tremendous terminology and methodology about it, has deceived him-

self in the belief that he was dealing with an objective reality.

Reality of Race Differences

For nearly two centuries anthropologists have been directing their attention principally towards the task of establishing criteria by whose means races of mankind might be defined. All have taken completely for granted the one thing which required to be proven, namely, that the concept of race corresponded with a reality which could actually be measured and verified and descriptively set out so that it could be seen to be a fact. In short, that the anthropological conception of race is true which states that there exist in nature groups of human beings comprised of individuals each of whom possesses a certain aggregate of characters which individually and collectively serve to distinguish them from the individuals in all other groups.

Stated in plain English this is the conception of race which most anthropologists have held and which practically everyone else, except the geneticist, accepts. When, as in recent years, some anthropologists have admitted that the concept cannot be strictly applied in any systematic sense, they have thought to escape the consequences of that fact by calling the term a "general" one, and have proceeded to play the old game of blind man's bluff with a sublimity which is almost enviable. For it is not vouchsafed to everybody to appreciate in its full grandeur the doctrine here implied. The feeling of dissatisfaction with which most anthropologists have viewed the many laborious attempts at classification of human races has not, on the whole, succeeded in generating the unloyal suspicion that something was probably wrong somewhere. If there was a fault, it was generally supposed, it lay not with the anthropologist but with the material, with the human beings themselves who were the subject of classification and who always varied so much that it was difficult to put them into the group where they were conceived to belong, and this was definitely a nuisance, but happily one which could be overcome by the simple expedient of "averaging,"—the principal task of the student of "race."

Race No Omelette

The process of averaging the characters of a given group, knocking the individuals together, giving them a good stirring, and then serving the resulting omelette as a "race" is essentially the anthropological process of race-making. It may be good cooking but it is not science, since it serves to confuse rather than to clarify. When an omelette is done it has a fairly uniform character, though the ingredients which have gone into its making may have been variable. This is what the anthropological conception of "race" is. It is an omelette which corresponds to nothing in nature. It is an indigestible dish conjured into being by an anthropological chef from a number of ingredients which are extremely variable in the characters which they present. The omelette called "race" has no existence outside the statistical frying-pan in which it has been reduced by the heat of the anthropological imagination.

It is this omelette conception of "race" which is so meaningless,—meaningless because it is inapplicable to anything real. When anthropologists begin to realize that the proper description of a group does not consist in the process of making an omelette of it, but in the description of the character of the variability of the elements comprising it, its ingredients, they will discover that the fault lies not with the materials but with the conceptual tool with which they have approached its study.

That many differences exist between different groups of human beings is obvious, but the anthropological conception of these is erroneous, and the anthropological approach to the study of their relationships is unscientific and pre-Mendelian. Taxonomic exercises in the classification of assemblages of phenotypical characters will never succeed in elucidating the relationships of different groups of mankind to one another for the simple reason that it is not assem-

blages of characters which undergo change in the formation of the individual and of the group, but single units which determine those characters. One of the great persisting errors involved in the anthropological conception of race has been due to the steady refusal to recognize this fact. The fact that it is not possible to classify the various groups of mankind by means of the characters which anthropologists customarily use, because these characters do not behave as pre-Mendelian anthropologists think that they should behave, namely, as complexes of characters which are relatively fixed and are transmitted as complexes, but behave instead in a totally different manner as the expressions of many independent units which have entered into their formation.

The materials of evolution are not represented by continuous aggregates which in turn determine particular aggregates of characters, but by discontinuous packages of chemicals, each of which is independent in its action and may be only partially responsible for the ultimate form of any character. These chemical packages are the genes, with which most anthropologists are still scarcely on terms of a bowing acquaintance. These genes retain both their independence and their individual character more or less indefinitely, although they are probably all inherently variable and, in time, capable of mutation. For these reasons any conception of race which operates as if inheritance were a matter of the transmission of gross aggregates of characters is meaningless.

The principal agencies of evolutionary change in man are primarily gene variability and gene mutation, that is to say, through the rearrangement of gene combinations in consequence of the operation of many secondary factors, physical and social, and change in the character of genes themselves. In order to appreciate the meaning of the variety presented by mankind today it is indispensably necessary to understand the manner in which these agencies work. Thus, in man, it is practically certain that some forms of hair, and skin color, are due to mutation, while still other forms are due to various combinations of these mutant forms with one another as also with non-mutant forms. The rate of mutation for different genes in man is unknown, though it has been calculated that the gene for normal clotting mutates, for example, to the gene for haemophilia in one out of every 50,000 individuals per generation. It is highly probable, for example, that such a mutation occurred in the person of Queen Victoria, a fact which in the long run may perhaps prove her chief claim to fame. Mutation of the blood group genes is, however, known to be very slow, and it is unlikely that such mutations have occurred since the apes and man set out upon their divergent evolutionary paths. Mutation of skin color genes is also very slow, while mutation of hair form genes is relatively frequent.

If we are ever to understand how the differing groups of mankind came to possess such characters as distinguish the more geographically isolated of them, and those of the less isolated more recently mixed, and therefore less distinguishable, groups, it should be obvious that we shall never succeed in doing so if we make omelettes of the very ingredients, the genes, which it should be our purpose to isolate and map. We must study the frequencies with which such genes occur in different groups. If, roughly speaking, we assign one gene to every component of the human body it should be fairly clear that as regards the structure of man we are dealing with many thousands of genes. If we consider the newer genetic concepts which recognize that the adult individual represents the end-point in an interaction between all these genes, the complexities become even greater. The morphological characters which anthropologists have relied upon for their "racial" classifications have been very few indeed, involving a minute fraction of the great number of genes which it would actually be necessary to consider in attempting to make any real, that is to say, genetically analytic, classification of mankind.

To sum up, the indictment against the

anthropological conception of race is (1), that it is artificial; (2) that it does not agree with the facts; (3) that it leads to confusion and the perpetuation of error, and finally, that for all these reasons it is meaningless, or rather more accurately such meaning as it possesses is false. Being so weighed down with false meaning it were better that the term were dropped altogether than that any attempt should be made to give it a new meaning.

If it be agreed that the human species is one and that it consists of a group of populations which, more or less, replace each other geographically or ecologically and of which the neighboring ones intergrade or hybridize wherever they are in contact, or are potentially capable of doing so, then it should be obvious that the task of the student interested in the character of these populations must lie in the study of the frequency distribution of the genes which characterize them—and not in the study of entities which have no meaning.

In conclusion, let me say that I realize how unsatisfactory this paper is, and that I cannot expect to have convinced you, within the short space of fifteen minutes, of the meaninglessness of the anthropological concept of race. It may be that a notion so many times attacked during recent years is now passed beyond the reach both of scientific judgment and mortal malice, but in any event, may I be so bold as to hope that you will not feel as the Canon's wife felt about the threat to her belief in special creation?

Dr. Ashley Montagu's interesting history of the term race, shows certain ways it has outgrown any usefulness, even becoming a menace. Some of his views may draw fire from geneticists, for humankind differs greatly in many characteristics variously distributed. If these differences are real enough to allow objective groupings of people, such groups will differ just as much whether we call them 'races" as to invent a new term. If Dr. Montagu's idol smashing helps to clear the air it has served a very useful purpose.

The laboratory scientist shuns the market place and the politicians' rostrum. Unfortunately folks accustomed to reach for a microphone refuse to stay out of the laboratory if they see a chance to gain even reluctant support for their pet nostrum. Because "race" is a word which inflames the emotions, much fanatical nonsense has been spoken and written about it. "Class" is another word called upon to carry an impossible genetic load, as the history of the eugenics movement testifies. Strange perversions, allegedly sanctioned by careful laboratory research, perplex and enslave millions of people.

Research workers in those sciences which may become social dynamite through perversion or prostitution of conclusions, may have to defend the integrity of their science whether they like it or not. This is emphasized in the depths of biological absurdity recently reached by the champions of "racism" (a derivative word with very ugly connotations). Even the Norwegians have been read out of the Aryan fold by the dark-moustached "protector" of the destiny-freighted blonds. The color of Norwegian hair and eyes has not changed. Rugged Norse individualism has made it impossible for the most "nordic" group in the world to accept the Procrustean savagery of the "new order".

With racism thus divorced by its leading proponent from shape of head and color of hair, eyes, and skin, it is essential that anthropologists and biologists clarify their own minds and inform lay people what actually are the differences between the human races. The study of human relationships through an analysis of gene distribution is as yet limited mainly to the blood groups and to P.T.C. taste reaction. The technique offers a hopeful approach which needs to be further explored.

As far as research and observation have been able to prove, the chromosome number of all the human races is the same, and all of the five, seven, or ten races (depending on whom we follow) are inter-fertile. The blood of all races is built of the same pattern of agglutinins and antigens, and the appropriate blood type from one race can be transfused into any of the others without untoward effects. Thus in spite of the unquestionable physical differences (and less measurable mental and emotional difference) between groups of people, an imposing substrate of similarity underlies these differences. This must serve as a foundation for a world order willing to accept the differences as a challenge to developing useful specializations and not as a fatuous excuse for the enslavement or exploitation of one "race", class or nation by another.—EDITOR.

RUSSIAN CONTRIBUTIONS TO THE 1939 GENETICS CONGRESS

THE Genetic crisis in Russia prevented the attendance of any Russian delegates at the International Congress held at Edinburgh in August, 1939. Up to the last minute it was expected that there would be a considerable Russian delegation at the Congress. The papers or abstracts submitted by the Russian delegates for presentation to the Congress were on file with the Secretariat of the Congress at the time it was held. Since these papers were not read by the authors they were not included in the Proceedings of the Congress, which have recently been published. It is the wish of many of the Russian workers that these papers somehow be made available as a matter of permanent record. The papers dealing with Drosophila are being issued by the Drosophila Information Service as *D. I. S. 15* and thus will be available for Drosophila workers. Through the instrumentality of the American Documentation Institute the other contributions are being afforded supplemental publication so that genetic workers can obtain them as microfilm or as photoprints. In the following "Table of Contents" of Documents 1563, 1564 and 1565 of the A. D. I., (S) signifies that the summary and not the full paper is filed with the Documentation Institute.

A. Plant Genetics (A. D. I. Document 1563)

1. Karpechenko, G. D. Cytogenetics in the Service of Plant Breeding. (S)
2. Koltzoff, N. K. On the Methods of Artificially Inducing Polyploids by Treatment with Colchicine.
3. Kostoff, Dontcho. Relation, Degrees and Phylesis of Certain *Nicotiana* Species. (S)
4. ————————. Studies on Atypical Growth in Plants.
5. Mostovoj, K. I. Cases of Constitutional Sterility of Plants.
6. Rozanova, M. A. Significance of Amphidiploidy and Autopolyploidy for Problems of Phylogeny.
7. Rybin, V. A. The Role of Interspecific Hybridization in the Polymorphism of *Prunus Spinosa* L.
8. Sveshnikova, I. N. Significance of the genus *Vicia* for the study of form evolution through the method of comparative cytogenetical analysis of species.
9. Sinskaya, E. Composition of Natural Populations of Higher Plants.
10. Volotov, E. N. On the Production of Polyploids in the Poppy (*Papaver somniferum* L.) Under the Action of Colchicine.
11. Zebrak, Anton R. Experiments on Obtaining Amphidiploids in Wheat.

B. Human Genetics (A. D. I. Document 1564)

1. Bunak, V. V. Genetic Analysis of Iris Pigmentation in Man. (S)
2. Ignatiev, M. V. The Curves of Distribution and Correlations Between Relatives in an Isolated Population.
3. Volotzkoy, M. V. Genetics of Skin Relief (Dermatoglyphics).

C. Animal Genetics (A. D. I. Document 1565)

1. Altshuler, V. E. The Effect of Hereditary Differences of Sires and of Environment on the Variability of the Average Records of Sires' Daughters. (S)
2. Frolova, S. L. Peculiarities of Maturation and Development of the Eggs of *Bombyx mori* L. Under Conditions of Artificial Parthenogenesis.
3. Kalabukhov, N. Some Ecological Adaptive Characters in Closely Related Species of Rodents.
4. Kushner, H. F. The Constitution and Productivity of Agricultural Animals in Relation to the Oxidising Properties of their Blood. (S)
5. Patrushev, V. I. Physiological and Biochemical Investigations of Domestic Animals in Connection with their Productivity. (S)
6. Schroder, Vera. Physico-chemical Methods of Sex Regulation of the Progeny of Mammals.
7. Shaskolsky, D. W. Formulae for Hereditary Fixation in Bee Mating Systems.

The papers are filed in the American Documentation Institute under three document numbers, corresponding to the three classifications, Plant Genetics, Human Genetics, Animal Genetics. The whole series of twenty papers may be obtained by ordering Documents 1563, 1564 and 1565. The price for the whole series on microfilm is $1.21. Document 1563 (Plant Genetics) may be obtained on microfilm for 57c, in photoprints for $3.90. Document 1564 (Human Genetics) may be obtained for 27c on microfilm, 90c in photoprints. Document 1565 (Animal Genetics) may be obtained for 37c on microfilm, $1.90 in photoprints. Orders for these documents should be sent to the American Documentation Institute, 2101 Constitution Ave., Washington, D. C. Include with your order the Document Number of the materials desired and remittance to cover the exact cost of this service.

GALAX: THE GENUS AND ITS CHROMOSOMES

J. T. Baldwin, Jr.*

THE genus *Galax L.* is a monotypic member of the family Diapensiaceae (Figure 2). It occurs naturally from northern West Virginia and northwestern Maryland to central Georgia and central Alabama and from eastern Virginia to central Tennessee. That distribution is shown on Map *A* (Figure 3), on which counties are outlined and on which each circle represents a single station, or, in some instances, several stations close together.†

The writer[1] reported twelve somatic chromosomes for one species in each of four of the six genera of Diapensiaceae and twice that $2n$-number for *Galax*. Then, for several reasons—chromosome-number variance in such a conservative family, designation by florists of large- and small-leafed galax (commonest common name for plant), and the opinion of Fernald[3] that *G. aphylla* migrated from the old Appalachian upland into the younger coastal plain — the writer considered it possible that a 12-somatic-chromosomed race of *Galax* might occur and, if so, might give a basis for explaining the size differences in the plants, and, likewise, an insight into the distributional history of the species. Cytological examination of plants from only a few stations revealed the existence of such a race. Relative geographic occurrence of stations for diploid ($2n = 12$) and tetraploid ($2n = 24$) galax was then determined, several hundred plants from 117 stations being examined cytologically (Map *B*, Figure 3). In a few cases, two stations close together are designated singly on the map. A table of the stations has been placed in the files of the United States Department of Agriculture Library as American Documentation Institute‡ Document No. 1592. Specimens of the plants are in the University of Michigan Herbarium, the Gray Herbarium, the Herbarium of the New York Botanical Garden, and the Herbarium of the Missouri Botanical Garden, and the U. S. National Herbarium.

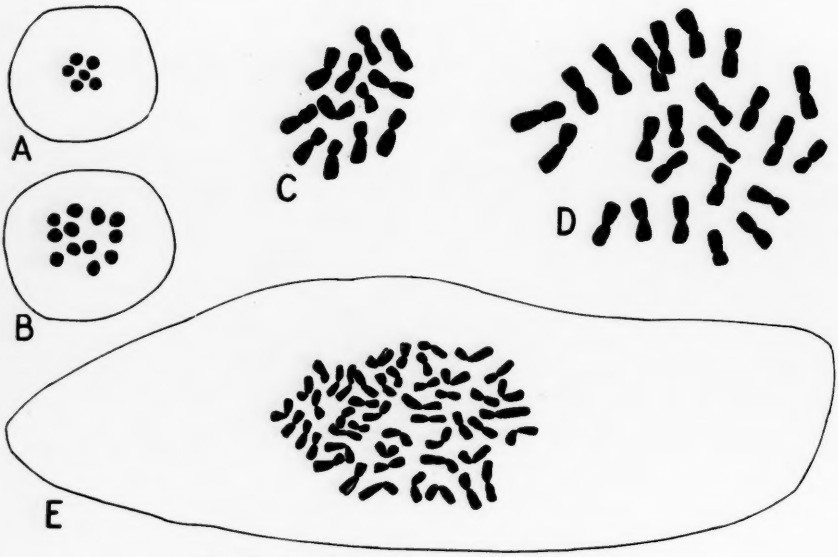
Most of the stations were visited by the writer in the summer of 1940. However, living plants were sent from some of the stations by various individuals (see A. D. I. Document No. 1592) to whom the writer is indebted. Usually, material fixed in the field during the day was studied cytologically that same night in a convenient laboratory, hotel, tourist house, or private residence.

Chromosome counts, both gametic and somatic, were made from aceto-carmine smears. For the one, pollen mother-cells, fixed in Carnoy's solution, were used: n=6 (Figure 1*A*), n=12 (Figure 1*B*); for the other, immature flowers, tips of

*Papers from the Department of Botany of the University of Michigan, No. 772. Investigation supported by Faculty Research Fund, Project No. 540.

†The map is based upon specimens borrowed from the Gray Herbarium, the United States National Herbarium, and herbaria of the New York Botanical Garden, of the Missouri Botanical Garden, and of Cornell University, Duke University, West Virginia University, University of Michigan, University of Tennessee, and University of Georgia. To the officials of these institutions the author expresses his appreciation for the loans. Also, the map is based upon the following: Mohr,[9] "waterfall near Pulpit Rock," Clay County, Alabama; Millspaugh,[8] near Nuttallburg," Fayette County, and "Dille Farm near Morgantown," Monongalia County, West Virginia; letter of Joseph E. Harned,[5] with reference to the occurrence of *Galax* in Maryland, "the only station I have noted is near Cumberland"; and specimen No. 784, private herbarium of Ruskin S. Freer, "just S. of Tyser's Ferry, Northumberland Co., Va.," May 7, 1933.

‡Table 1 has been issued by us through Auxiliary Publication, and may be obtained from the nonprofit Bibliofilm Service, American Documentation Institute, 2101 Constitution Avenue, Washington, D. C., by ordering Document No. 1592, remitting 27 cents for copy in microfilm, readably enlarged full-size on reading machine or hand viewer, or 90 cents for copy in form of paper photoprints readable without mechanical aid.



METAPHASIC CHROMOSOMES OF *GALAX*

Figure 1

A-B—Pollen mother-cells: $n = 6$ and 12. *C-D*—Smears from leaf cells: $2n = 12$ and 24. *E*—An atypical stem-tip cell: $2n = 48$. Magnification, *A-B*, *ca* × 1500; *C-D*, *ca* × 4500; *E*, *c.* × 3000.

underground stems, and young leaves, all being processed according to Baldwin's[2] modification of Warmke's[13] method: $2n = 12$ (Figure 1*C*), $2n = 24$ (Figure 1*D*). In the relatively few meiotic divisions studied, only bivalent associations were observed — no multiple configurations as frequently found in autopolyploids. (Probably in most autopolyploids, as time passes, there is an evolution toward bivalency). One additional somatic number was determined: a single stem-tip cell of a diploid plant, in Avery County, North Carolina, had forty-eight somatic chromosomes (Figure 1*E*).

Analysis of Map 3*B* shows that the diploid and tetraploid races of galax are not separated by geographic barriers: the diploid occurs throughout the range of the species except in the Virginia coastal plain, where only the tetraploid has been found. In addition to the above, and a few scattered stations in North Carolina and Georgia, the tetraploid grows in the mountains from southern Virginia through North Carolina into northern Georgia and South Carolina. And interestingly enough, is thus chiefly within "all the territory worth while for 'picking' the Gal.x" (T. N. Woodruff[14]).*

*Every year hundreds of North Carolinians earn a substantial part of their income from picking galax leaves, which, tied in bunches of twenty-five each, are normally sold, via local buyers, for eventual floral and decorative use throughout the United States and in Canada, Europe, Asia, and Australia. A good picker may gather ten thousand leaves in a day. "These leaves are gathered on a commercial scale all over the Blue Ridge Mountain range and foothills through North Carolina, from the Virginia line on the north to the Georgia on the south. This embraces a territory of about two hundred miles in length and from ten to thirty miles wide"—this from a letter of October 30, 1940, from T. N. Woodruff of Lowgap, North Carolina. Mr. Woodruff is one of the biggest dealers in galax.

The industry in this plant was well-established by the close of the last century. Lounsberry[7] wrote in 1901: "the business has passed into the hands of many." F. M. Richards, dealer in "evergreens" at Spruce Pine, North Carolina, showed the writer a bill of sale, dated October 15, 1900, for a shipment of leaves to Canada. And it is said that galax was sent to England in 1902 for the coronation ceremonies of Edward VII. In Virginia, near the upper limit of the commercial galax area, there is a town called Galax, the first lots for the town having been sold in December, 1903 (*Galax Post Herald*[4]).

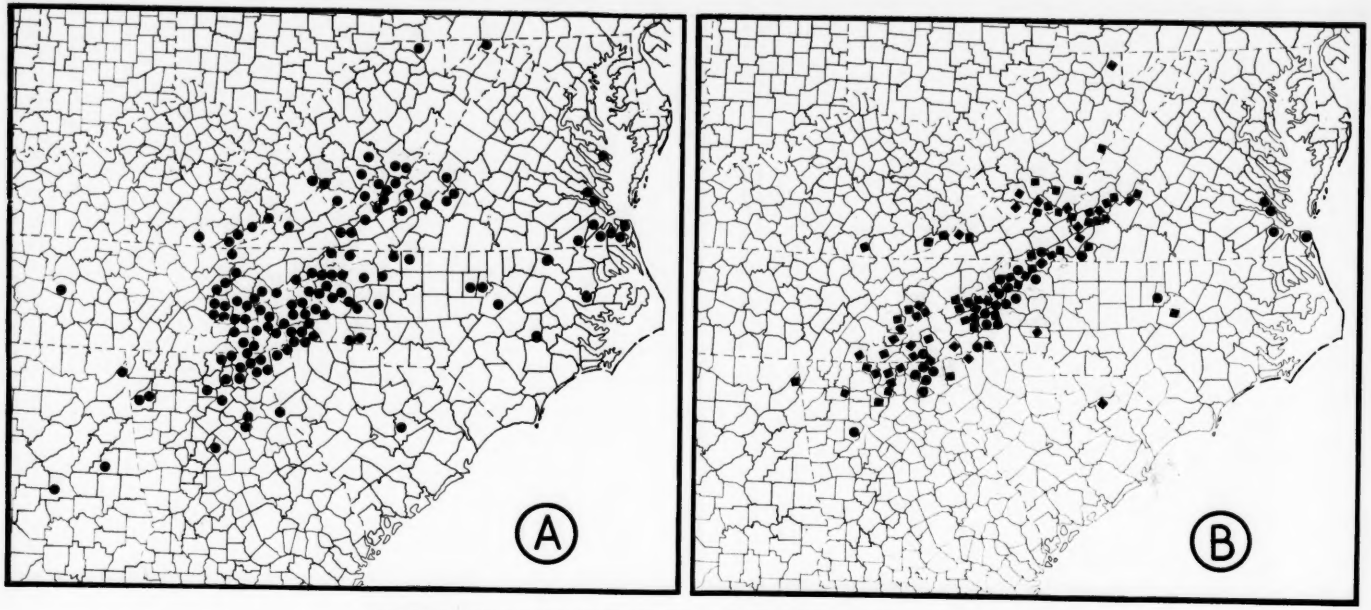
GALAX IN BLOOM
Figure 2

Inflorescences and shiny leaves of *Galax* growing with *Trillium* and *Rhododendron*. Photographed by Carlos C. Campbell, June 23, 1934, in the Great Smoky Mountains National Park. The Diapensiaceae, consisting of thirteen described species in six genera, of which the monotypic *Galax* is one, are, as a family, circumpolar with most of the representatives either in the eastern United States or in eastern Asia. Except for a tetraploid race of *Galax*, the other cytologically known members of the family are diploid and have a $2n$-number of twelve chromosomes.

beginning at the northern limit of that territory and extending just south of it. Therefore, as now understood, the tetraploid, absent from the northern and western parts of the distributional area of the species, is, accordingly, restricted to the eastern and eastward-looking part of the specific range.

The two races are separated by no obvious ecologic barrier. Both races are found in the coastal plain; for example: the tetraploid grows near Norfolk, Virginia; the diploid, near Hartsville, South Carolina. Likewise, both races are in the high mountains: the tetraploid at an elevation of 5,964 feet atop Grandfather Mountain in North Carolina, the diploid *ca.* 5,200 feet on Mount LeConte in Tennessee. Both races are ericaceous-like in habitat preferences. The writer has always found *Galax* associated with either *Kalmia* or *Rhododendron*. Other genera frequently observed in this association are *Oxydendrum*, *Vaccinium*, *Epigaea*, *Leucothoë*, *Pinus*, *Quercus*, *Castanea*, *Acer*, *Cornus*, *Ilex*, *Mitchella*, *Liriodendron*, etc. Usually at lower elevations, frequently at higher elevations, *Galax* grows close to streams or bodies of water. It is, in general, a mesophyte.

No attempt has been made to hybridize the two races. That plants with other chromosome numbers, e.g., $2n = 18$ or 36, were not discovered in the fairly well-sampled galax population, is indicative of physiological isolation of the diploid and tetraploid races. Morphologically they are very similar, and this is not unexpected, for as Huxley[6] observes: "Speciation due to genetical isolation arising *per saltum*, as happens by the alteration of the ploidy, will often be accompanied by changes consequent on the changed genome-constitution, but



DISTRIBUTION OF GALAX AND OF CHROMOSOME RACES

Figure 3

Map *A* — Distributional range of *Galax*: from northern West Virginia and northwestern Maryland to central Georgia and central Alabama and from eastern Virginia to central Tennessee. States and counties are outlined. Each circle represents a known station based on reliable reports or herbarium specimens. These reports and specimens did not include a chromosome analysis. Map *B* — Distribution of chromosome races of *Galax*. Squares represent stations for the diploid; circles, for the tetraploid. The commercial galax area extends along the Appalachian Mountains in a region in which the tetraploid predominates. Tetraploid plants are potentially the larger, though under unfavorable conditions they may be as small as diploids. under optimum conditions.

again is unlikely to be accompanied by nearly so much character-differentiation as geographical or ecological speciation." Diploid plants of galax, as observed, may have leaves up to a breadth of about four inches; the tetraploid, up to a breadth of six. In each race, this maximal size is reached only under most favorable growing conditions: a shaded, mesic habitat in the mountains with a soil that is rich, acid, and humus-covered. If conditions for growth are not favorable, either race may produce leaves less than two inches in diameter. One may safely make the general statement that the tetraploid is potentially more robust and bigger than the diploid. But only when conditions for growth were very good has it been possible, except microscopically, to separate the two races with assurance, yet, in distinguishing between big- and little-leafed galax, the mountain people probably make this distinction. The industry, concentrated as it is within the region where the tetraploid chiefly occurs and where conditions seem optimum for vigorous growth, is doubtless largely founded on the tetraploid race, for the trade is mostly in the bigger leaves. Galax grows under comparable conditions in eastern Tennessee, but "very little is gathered in that territory" (T. N. Woodruff[14]). Only the diploid has been found there.

Fertile parthenogenetic diploids are produced by tetraploid maize, so "the evolutionary trend among autopolyploids is not necessarily unidirectional" (Randolph and Fischer[11]). In galax, however, because of the relative distribution of the 12-somatic- and 24-somatic-chromosomed races and because of a uniform $2n$-condition of twelve among the other cytologically known Diapensiaceae,[1] it is reasonable to assume that the tetraploid galax is a derivative of the diploid.

Discontinuous occurrence of the two races outside the main area of the species adds weight to the opinion of Fernald[3] that *G. aphylla* migrated from the old Appalachian upland into the younger regions and, also, is suggestive of the origin of the tetraploid in the mountains.

Randolph[10] has shown experimentally and Tischler[12] circumstantially that extreme temperatures may induce polyploidy. Perhaps diploid galax in the high mountains was subjected to extreme cold shock during a glacial period, or possibly a forest fire supplied heat treatment at a critical stage in the ontogeny of a galax flower, which develops in late summer and fall and undergoes meiosis during the following May or June. If glaciation were a factor in causing tetraploidy in galax, certain other plants characteristic of the old Appalachian system should have intraspecific chromosome races.

Summary

Galax aphylla is unispecific but has two chromosome races: diploid ($n = 6$, $2n = 12$) and tetraploid ($n = 12$, $2n = 24$). The species occurs from northern West Virginia and northwestern Maryland to central Georgia and central Alabama and from eastern Virginia to central Tennessee. The diploid grows throughout the range of the species except in the Virginia coastal plain, where only the tetraploid has been found. This latter race is especially concentrated in the area extending from southern Virginia through the North Carolina mountains into Georgia and South Carolina. The distribution of the species and of its races is mapped in this paper. The discontinuous occurrence of the two races outside the main area of the species adds to the evidence that *G. aphylla* went from the old Appalachian upland into the geologically younger regions.

Since no geographic or ecologic barrier was found between the two races, they are probably isolated genetically: only diploid and tetraploid plants, among several hundred examined cytologically, were discovered from 117 stations distributed throughout the range of the genus. A single atypical cell with forty-eight somatic chromosomes was found. Most of the chromosome counts were made from leaf and stem-tip smears.

The tetraploid is potentially larger than the diploid but actually is often as small. The difference is expressed under favorable growing conditions.

There is a considerable industry in the leaves of galax, trade being mostly in the bigger leaves. The commercial galax area coincides pretty well with the region where the tetraploid is concentrated and where conditions for vigorous growth seem optimum.

Distribution of the tetraploid is indicative of its origin in the high mountains now found in North Carolina. Cold shock during a glacial period and heat effect during a forest fire are suggested as possible agents in inducing polyploidy.

Literature Cited

1. Baldwin, J. T., Jr. Chromosomes of the Diapensiaceae. *Jour. Hered.* 30:169-171. 1939.
2. ————. Chromosomes from leaves. *Science* N. S. 90:240. 1939.
3. Fernald, M. L. Local plants of the inner coastal plain of southeastern Virginia, Part III. *Rhodora* 39:465-491. 1937.
4. *Galax Post Herald,* January 13, 1938. Galax, Virginia.
5. Harned, Joseph E. Letter of June 25, 1940, to Reverend Fred W. Gray.
6. Huxley, J. S. Toward the new systematics, in The New Systematics. Oxford: Clarendon Press. 1940.
7. Lounsberry, Alice. Southern Wild Flowers and Trees. New York: F. A. Stokes Company. 1901.
8. Millspaugh, C. F. Flora of West Virginia. *Bull 24. W. Va. Exp. Station.* Charleston, W. Va.: Moses W. Donnally. 1892.
9. Mohr, C. Plant Life of Alabama. *Contr. U. S. Nat. Herb. VI.* Philadelphia: D. Heartt. 1901.
10. Randolph, L. F. Some effects of high temperature on polyploidy and other variations in maize. *Proc. Nat. Acad. Sc.* 18:222-229. 1932.
11. ———— and H. E. Fischer. The occurrence of parthenogenetic diploids in tetraploid maize. *Proc. Nat. Acad. Sc.* 25:161-164. 1939.
12. Tischler, G. Die Bedeutung der Polyploidie für die Verbreitung der Angiospermen. *Bot. Jahrb.* 67:1-36. 1935.
13. Warmke, H. E. A permanent root tip smear method. *Stain Tech.* 10:101-103. 1935.
14. Woodruff, T. N. Letter of October 30, 1940, to J. T. Baldwin, Jr.

Sex-Ratios in Sheep Twins

The data comprise 3711 twins and singles and in addition there were 42 triplets not included in the table. The triplets were evenly divided between males and females and of the twins and singles 1835 were males and 1876 were females. This yields a sex ratio of 49.4% males to 50.6% females which agrees closely with the average for previous reports.

However, a closer analysis of the data shows that there is a distinct difference in the ratio of lambs born as singles and those born as twins of like sex. The singles had 51.7% males and 48.3% females, whereas for the twins of like sex there were 45.0% males and 55.0% females.

The preponderance of females among twins of like sex is consistent for all the groups, and the total shows a significant deviation from the sex ratio of all lambs as well as from the 50:50 ratio. For the individual groups the deviation from expected is not significant except for the New Zealand Corriedales. A summation of chi-squares for each group yields a value of 13.15 for 5 degrees of freedom, a value between the 5% and 1% point. If the totals only are considered, the chi-square value is 7.59, also highly significant. Thus the evidence favours the view that some factor is at work to cause a surplus of twin females or a deficiency of twin males to be born.

The latter seems to be the more probable in view of the number of twin females in relation to twins of mixed sexes. No definite cause can be ascribed for the deficiency of twin males of like sex, although the surplus of single males may suggest that intrauterine mortality of one of a set of twin males may occur more frequently than in female twins or in twins of unlike sex. This would then cause some single males to be born from what were twin male conceptions and would explain the situation that has been observed.

Further data are required before definite conclusions can be drawn, but the number of lambs involved and the consistency of the data appear to overrule the chance factor in deviations of sex ratio.—K. Rassmussen — in *Sci. Agric.* 11:758-759. 1941.

THE INHERITANCE OF EQUINE COAT COLOR

II. The Dilutes, with Special Reference to the Palomino

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RECENTLY, the color or colors which distinguish a horse as a Palomino have been of considerable interest to horse breeders and to animal geneticists. The Palomino is distinguished by a cream-colored body and white mane and tail. The body color may vary considerably in shade from a dark gold to a light, washed-out yellow. Horses of the deep-cream or golden color have enjoyed wide popularity, especially in the Southwest. However, difficulty has been encountered in fixing the desired shade and color.

It is generally agreed that a horse of the desired color is heterozygous for at least one pair of genes. In practice, Palominos are commonly produced by mating Palomino stallions to self-colored chestnut or sorrel mares. From information obtained from breeders in Texas and California it appears that approximately 50 per cent of the get of such a cross are of the desired color. When Palominos are interbred, the color "runs out," according to breeders, producing an individual with a body color so light that it is practically indistinguishable from white. The eyes of such individuals are almost devoid of pigment and present a bluish-pink appearance. On close direct observation the blue is seen to be located on the edge of the iris, while the pink is due to the blood vessels of the eye. The skin of the body is pink, a condition which is particularly noticeable about the eyes and nostrils. This color has been variously called albino, pseudo-albino, "blanco," and many other descriptive names. It is not desired. Consequently, horses possessing such a color have seldom been used in breeding operations. Fortunately, Troop D of the New York State Police has used a stallion of this color in its breeding operations and an opportunity has been afforded the authors of studying the results at first hand.

Information on the inheritance of the Palomino color has been obtained from a study of the inheritance of the color of ponies registered in the American Shetland Stud Book, visits to Palomino breeding establishments, and reports from breeders. In the visits to breeders all individual horses were observed, and information recorded on the spot. In some cases color photographs were taken for future reference. Often hair samples were taken and microscopic studies made of the visual appearance ot pigment granules and their distribution.

Review of the Literature

Recently, Castle[1,2] and Gremmel[4] have mentioned the Palomino color and have proposed symbols and gene interactions to explain its appearance. Earlier, however, other investigators had reported on the occurrence of this color, but called it cream. Examination ot many such horses convinces us that the colors are identical from the standpoint of their inheritance.

Apparently the first study of color inheritance of horses which considered the cream color was that of Wilson.[9] He stated "Creams are usually found where duns are found" and considered that cream was a variety of dun if it possessed black points, but was a variety of chestnut otherwise. Here it might be well to mention that most

*The authors are indebted to a number of breeders of Palomino horses in Texas and in California for their cooperation in the course of this investigation. We also wish to express our appreciation of the help afforded by the personnel of Troop D, New York State Police, Oneida, New York.

investigators of the inheritance of coat color in horses group all those horses possessing a light body color, a black mane, a black tail, dorsal stripe, and often with zebra-striped legs as duns. On the other hand, many such horses, especially those with the more yellow body color, are commonly called "buckskins" by the American horseman. One of the sires mentioned in Wilson's paper which he considered a dun was described in a footnote as a "dun or cream, with white or cream mane and tail." Obviously, Wilson was dealing with a color similar to the cream considered in this study. According to Crew and Smith,[3] Wreidt felt that cream was an unfixable heterozygous condition. This point of view has been upheld by breeding results.

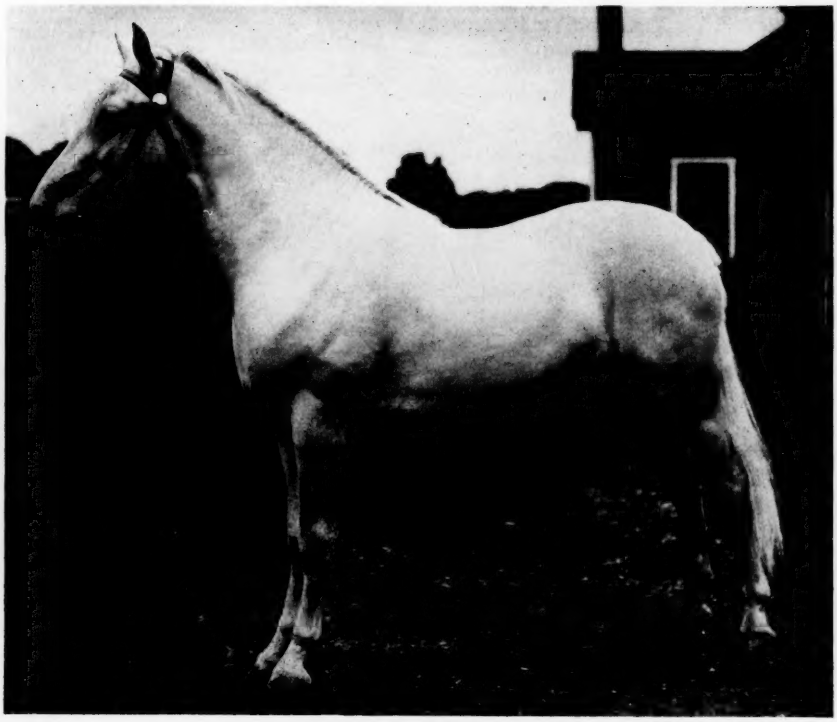
Heizer[5] presented data which showed that creams may result when dun, mouse, or cream horses are bred on other colors. Therefore, he considered that dun, mouse, and cream are produced by a dominant dilution gene superimposed over certain basic body colors. This attitude has been held by most writers.

Tuff,[8] in a stud book study of Norwegian horses, also came to this conclusion. In addition, he postulated a pair of genes responsible for quantity of pigmentation, which, in the heterozygous condition, reduced pigment, and in the homozygous recessive condition produced an albino. This he termed the albino factor. He stated that homozygous individuals are albino, while in the heterozygous condition this gene reduces chestnut to cream, bay or brown to buckskin, and dun to light dun, but has no influence on black or mouse. Of 2,526 matings of the Westland horse, of which 96 per cent carried the dominant dilution gene and over 550 carried the albino factor, not one case of an albino horse was reported. Undoubtedly some were born but not registered. In his English summary, Tuff pointed out that the dominant dilution gene reduces chestnut to "reddish dun," and the albino gene reduces chestnut to cream. His illustrations show reddish dun to be similar to deep cream or golden Palomino, while the cream is about what we consider as light cream.

Earlier, based on a review of the work of Wriedt, Crew and Smith[3] had offered a similar genic arrangement to explain the colors under discussion. This explanation raises several questions which should be answered before this problem can be completely solved. What is the appearance of dun, mouse, or reddish dun horses which are homozygous for the dominant dilution gene? What is the effect of the albino gene in combination with the reddish dun color? Does the albino gene in the homozygous condition produce albino regardless of basic color genes present?

Gremmel[4] has recently proposed an hypothesis for the inheritance of color in horses based on qualitative and quantitative effects of genes at three major loci. His theory was developed from observation of colors resulting when horses of the various colors were mated, for which data were not given in his paper, chemical studies of hair pigment, and histological studies of distribution of pigment granules. He was of the opinion that pseudo-albino, apparently what others have called albino, was the homozygous recessive for the three pairs of genes. It was suggested that one dominant at the first locus produced a Palomino, while two dominant genes at this locus produced a red ysabella or sorrel. He stated, "The relation of the Palomino color to dun as suggested by some authors, including Tuff, can not be substantiated."

Considering the evidence of others, one might conclude that the typical Palomino color is produced by the two different genetic combinations. One combination would be the basic chestnut or sorrel plus a dominant dilution gene, which also dilutes bay or brown to dun, and black to mouse. The other would be chestnut or sorrel possessing a recessive member of a pair of genes responsible for basic pigment. The latter type would bear no relation to dun, though according to Tuff,[8] it would to



AN "ALBINO" STALLION
Figure 4

This stallion is a very light cream, with a pure white mane and tail. His eyes are pink, except for a blue edge of the iris. Genetically he is a homozygous dilute chestnut.

buckskin, which color varies only in degree from dun. Each would behave as a dominant, or perhaps we should say, as an incomplete dominant, for no one has shown that the effect of the so-called dilution gene is not cumulative, as is the effect of the albino gene according to Tuff.

Inheritance of the Palomino Color

Our problem has been to determine which condition applies, or whether both conditions apply, in the breeding of Palominos in this country. A study of the data obtained from Shetland ponies on this question indicates that a dominant gene is responsible for the creams, duns, and mouse colored ponies. As is shown in Table I, when ponies possessing the dominant dilution gene were mated to individuals possessing the same gene the progeny were mostly dilutes. When dilute individuals were crossed on solid-colored ponies the ratio of dilutes to non-dilutes was 131:136, a very close approximation to 1:1.

In this table the ponies possessing the typical Palomino color are designated as creams, for they are so listed in the Stud Book. A careful examination of a number of ponies of this color fails to reveal any indication that the color, type, or distribution of pigment is different from that of the Palomino. The data corroborate those previously

reported by several authors, including Heizer[5] and Tuff,[8] and indicate that a relationship between Palomino (cream) and dun does exist.

The results of our investigations in visits to Palomino breeders in California are summarized in Table II. In all cases the animals have been examined and classified as to color. Where possible the sire and dam of any animal, itself having progeny, were examined. The complete data for each stallion, the mares on which he was bred, and their progeny are included in Appendix Table I. As these records were collected over several years, the same terminology is not used in each case in Appendix Table I. However, light and cream Palominos refer to the lighter shades of the color, while "golden" refers to the darker shade. The word, Palomino, alone in these records refers to an intermediate shade which is second only to the golden shade in popularity. The term albino is used in the sense that the individual was of a very light yellow, almost white with bluish-pink or "china" eyes and pink skin.

With reference to either Table II or Appendix Table I*, the reader should appreciate that these data do not represent a random sample of the progeny of the crosses listed. A high proportion of the off-color individuals, such as those of the basic colors, were not kept by Palomino breeders, but were sold or otherwise disposed of early in life.

Reports from breeders of Palominos are summarized in Table III. The individual horses were not seen by the authors. The breeders were instructed as to the colors which we include under the various names and, in the main, their reports appear to be quite definite, though we cannot show that all sources of error have been removed.

The breeders reported that when their Palomino stallions were bred to chestnut or sorrel mares, 40 to 50 per cent of the progeny were of the Palomino color. The remainder were chestnut or sorrel. One breeder reported a like percentage of Palomino foals by a Palomino stallion bred to mares of all colors.

The data summarized in Table III are shown in Appendix Table II in detail under the eight stallions involved.

Breeding results of the stud operated by Troop D, New York State Police at Oneida, New York, bear out the same general picture. In the case of this information every individual has been minutely examined, photographs taken, and hair samples taken for histological examination.

The stallion in service, shown in Figure 4 has since been sold; so that these interesting breeding operations are not being continued. He was a very light cream, almost white in color, with a pure white mane and tail. His eyes were pink with blue edges about the iris, and he had pink skin. The star on his forehead could only be readily distinguished after his forehead was washed with a damp cloth. He was what we have been calling an albino, for want of a better name, and was the color which some California breeders call blanco.

This stallion, King, was sired by a golden Palomino with white mane and tail and with normal eyes. King's dam was of the same color. His breeding record follows in Table IV. In cases where the same mares to which King was bred had also produced foals sired by other stallions, this information is included to the right of the table.

This same stallion was bred on fifteen outside mares, all of which were of basic colors, bay, brown, or black. Each one produced either a dun, mouse or Palomino foal, not one of which possessed the china eyes of the sire.

On one occasion a small black mare with a typical dun-colored foal at foot was seen in a pasture near the Barracks. First inquiry indicated that the foal was sired by a sorrel stallion, but fur-

*Appendix Tables I and II are published as Supplementary Document 1594 of the American Documentation Institute. (See page 249 for ordering directions.) Price on microfilm 23c; on photoprint 50c.

ther inquiry and checking of breeding records showed that the foal was sired by an albino son of King's. On another occasion a three-year-old colt by King and out of a brown mare was listed on the records as a Palomino with china eyes. This fact did not check with theory. Upon examination it proved to be a dun with black mane and tail, black stockings, and dorsal stripe.

Discussion

Our studies and observations lead us to the conclusion that the typical Palomino color is produced by the presence of a single gene responsible for reducing the intensity of the red pigment found in chestnuts and sorrels. The variations in body color are undoubtedly not only due to the genes responsible for varying the intensity of pigment in sorrels, but also to certain unidentified genes or gene interactions. It would appear that the basic chestnut with a white mane and tail plus the dilution gene produces the Palomino with the most desirable color. Contrary to the opinion of Gremmel,[4] it appears that it has also been demonstrated that a relation actually exists between dun and Palomino (cream) horses, for the gene responsible for reduction of pigment is not only found in the Palomino but is also found in dun horses.

It has been shown that individuals which are apparently homozygous for the gene responsible for the reduction of pigment, but lacking in the gene for black, are almost entirely devoid of color in the hair. Such individuals have white manes and tails, have pink eyes, save for an appearance of blue about the edge of the iris, and have pink skins. When bred on other colors they produce progeny all of which show the effect of reduction of pigment in the hair.

No evidence has been obtained which indicates that the homozygous condition of the dilution gene produces an albino if the gene for black is present. It is our opinion, based on insufficient data for acceptance as absolute proof, that, in the presence of the gene for black, the homozygous dominant dilution gene produces a washed-out, light dun.

No evidence has been obtained supporting the viewpoint that two different genes are responsible for the reduction of pigment in the horses and ponies considered in our study. This, however,

TABLE I. COLORS OF OFFSPRING WHEN DILUTES ARE DIFFERENTLY OR CROSSED ON BASIC COLORS

Color of parents	Color of offspring												
	Dun	Mouse	Cream	Bay	Brown	Black	Chestnut	Sorrel	Dilute	Non-dilute	Total
(a) dilute x dilute											
dun x dun								1		1	1
dun x mouse	1								1		1
dun x cream	1	4	2					1	7	1	8
mouse x cream	4	2	1						7		7
Total	6	6	3					2	15	2	17
(b) dilute x non-dilute											
dun x bay	6	12	2	4		2	1	3	9	10	19
dun x brown	2	1		4	3	3			3	10	13
dun x black	31	8	1	8	2	23		4	40	37	77
dun x chestnut	1						2		1	2	3
dun x sorrel	2	1		1	2			7	3	10	13
mouse x bay	4	1		6	1	2		1	5	10	15
mouse x brown	3	2		1	5	3			5	9	14
mouse x black	3	9	2		4	10		1	14	15	29
mouse x chestnut			2		1				2	1	3
cream x bay	1		4					2	5	2	7
cream x brown	1	5			3	2			6	5	11
cream x black	4	4	11		3	4	1	5	19	13	32
cream x chestnut			2						2		2
cream x sorrel	2		15					12	17	12	29
Total	66	32	49	24	24	49	4	45	131	136	267

TABLE II. OBSERVED RESULTS OF BREEDING PALOMINOS

Color of parents	Color of offspring						
	Albino	Palomino	Dun	Bay	Brown	Black	Chestnut or sorrel
Palomino x Palomino	6	3					
Palomino x dun		1					
Palomino x bay		12	3	5			4
Palomino x brown		2	4		2	1	
Palomino x black		4				1	1
Palomino x chestnut or sorrel		15					4
Palomino x gray		1					
Albino x albino	1						
Albino x dun	1						
Albino x brown		1					
Albino x black		1					
Albino x chestnut or sorrel		7					
Albino x gray		1					

TABLE III. RESULTS OF BREEDING PALOMINOS AS REPORTED BY BREEDERS

Color of parents	Color of offspring				
	Albino	Palomino	Dun	Bay	Chestnut or sorrel
Palomino x palomino	2	7			3
Palomino x dun		4	1		
Palomino x bay			1	2	
Palomino x brown					1
Palomino x black					1
Palomino x chestnut or sorrel		5			5
Palomino x gray					1
Dun x black		3			
Albino x dun			1		
Albino x bay		4			
Albino x brown			1		
Albino x chestnut or sorrel		3			

TABLE IV. OBSERVED BREEDING RESULTS WHEN ALBINO STALLION WAS BRED TO PALOMINO AND OTHER MARES

No. and color of mare	Offspring	Offspring from same dam
1. Bay	dun	
2. Dun	albino	To brown Thoroughbred stallion - produced one Palomino and one chestnut
3. Cream Palomino	albino	To brown Thoroughbred - produced one dun
4. Light dun	3 albino	
5. Golden Palomino	3 albino (some variation in body color)	
6. Cream Palomino	albino	When bred to albino son of King's produced albino
7. Bay	golden Palomino	
8. Dun	albino	When bred to brown Thoroughbred produced one dun and one brown
9. Cream Palomino	albino	When bred to brown Thoroughbred produced Palomino, light dun, and mouse

does not preclude the possibility that such might be the case in horses of different origin.

Summary

Data obtained from a study of Stud Book matings have led to the hypothesis that the Palomino color is produced by an incompletely dominant dilution gene superimposed over the basic chestnut or sorrel color. This same gene in combination with the other basic colors, bay, brown or black, produces a dilute which may be a dun, buckskin, or mouse.

Results of actual breeding practices of Palomino breeders support the hypothesis developed and further show that the homozygous dilute chestnut or sorrel is almost entirely devoid of hair pigment, has pink skin and china eyes. Individuals of this description have been termed albinos.

Literature Cited

1. Castle, W. E. The genetics of coat color in horses. *Jour. Hered.* 31:127-128. 1940.
2. ————. Mammalian Genetics. pp. 151-154. Harvard Univ. Press, Cambridge, Mass. 1940.
3. Crew, F. A. E., and A. D. Buchanan Smith. The genetics of the horse. *Biblio. Genet.* 6:123-170. 1930.
4. Gremmel, Fred. Coat colors in horses. *Jour. Hered.* 30:437-445. 1939.
5. Heizer, E. E. Color inheritance in horses. *Rec. of Proc. 24th Ann. Meet. Am. Soc. An. Prod.* 184-192. 1931.
6. Loen, Johs. Farge-nedarvinga hos Vestlandshesten (Fjordhesten) Oslo. 1938.
7. Salisbury, G. W. The inheritance of equine coat color. I. The basic colors and patterns. *Jour. Hered.* 32:235-240. 1941.
8. Tuff, Per. Genetiske undersokelser over hestefarver. *4 Nord. Veterinärmöt.* Sekt. VI, 1-28. 1933.
9. Wilson, J. The inheritance of the dun coat color in horses. *Proc. Roy. Dublin Soc.* 13:184-201. 1912.

✦

Biological Reclamation of Homo

If we have any residue of that superior primate intelligence of which we boast it is time to devote the most of it to the biological reclamation of the human animal. Otherwise civilization will perish. Let us go ahead and spend billions upon military preparedness, but shall we continue to withhold from the geneticist and the student of human constitution the few millions that are required to enable them to find out how to improve the quality of the human organism? Among the great in government, in industry, in science and in education, there are not a dozen who have lifted voices of protest against the debauching of a once promising human animal by culture and by the perverse refusal to learn his own biology. The leaders of society have nothing to offer except words, weapons and wails.

Pliny had an interesting and scientifically profitable time in observing the destruction of Pompeii, although he himself was fatally involved in that catastrophe. There are perhaps a few of us who are sufficiently cold-blooded in our scientific interest to be willing to sit calmly and take notes upon the liquidation of human affairs. But I am of the opinion that there is still something to be done about them, if we are willing to get busy at once. I am an optimist, not by disposition, but because I am a student of organic evolution and know that a wise use of the potent force of genetic selection can work miracles in the improvement of animal organisms, even when we know very little about the mechanism of heredity. I also have confidence that we can speedily acquire and utilize a knowledge of human genetics. Before we reach that stage of enlightenment (and we would better be quick about it) we must rid ourselves of the false prophets of cultural salvation and the witless preachers of human equality. The future of our species does not hang upon forms of government, economic adjustment, religious or social creeds, and purely environmental education. The future of man is dependent upon biology. We must have fewer and better men, not more morons and machines. — Hooton, E. A., *Why Men Behave Like Apes and Vice Versa*, Princeton University Press.

THE CHROMOSOME COMPLEX OF DOMESTIC SHEEP (*OVIS ARIES*)

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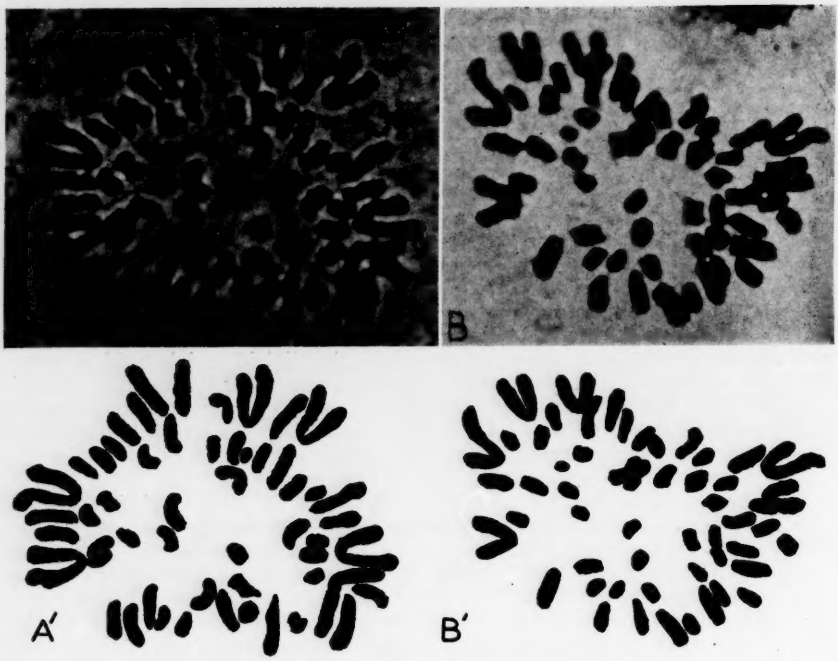
THE number of chromosomes reported by various workers for domestic sheep (*Ovis aries*) ranges from 33 to 60. In the earliest work, the technique used probably accounts for the low chromosome counts, but in recent work there seems to be a difference in the interpretation of the chromosome complex. Wodsedalek[11] reported the chromosome number in sheep as 33 for the male and 34 for the female. Krallinger[6] found 50-60 chromosomes in spermatogenesis of the Merino sheep and 30 in the primary spermatocytes. From studies on cells of the amnion, Shiwago[10] found 54 chromosomes in most of the cells. The animals from which he obtained the young embryos for his study were chiefly those of Merino breeding. Butarin[4] reported 54-56 chromosomes in the spermatogonial metaphase of the Arkhar (an Asiatic species of wild sheep) and 52-54 for the same stages in tissue from the fat-rumped ram. He observed one single unpaired V-shaped element. Butarin[5] followed this report with another in which he reported 60 as the diploid chromosome number for the Arkhar, the fat-rumped sheep, and hybrids between these. Novikov[7] found a diploid number of 60 chromosomes in the spermatogonial cells of the interspecific hybrid of the European Mouflon (*Ovis musimon*) and the domestic sheep (*Ovis aries*). No V-shaped chromosomes were observed in these spermatogonial divisions. From studies on the first maturation divisions in the Georgian fat-tailed sheep of Russia, Pachakadze[8] came to the conclusion that the haploid chromosome number was 30. Bruce[3] studied numerous spermatogonial cells from Merino sheep and found 60 chromosomes, all of which were comparatively short rod-like structures of uniform diameter. Berry[2] reported finding 54 chromosomes in the amnion cells from Rambouillet sheep. In the Leicester breed of sheep, Ahmed[1] found 54 and 27 to be the diploid and haploid chromosome number respectively. He observed three large V-shaped chromosomes in the spermatogonial metaphase and one of these was considered to be the *X*-chromosome.

From the literature cited above, it can be noted that reports from studies on the chromosome number in sheep may be divided into two groups, according to the number of chromosomes found and the type of tissue used. Most of the workers made their observations from testicular material and a majority of these gave the diploid number of chromosomes as 60. All of the studies on the testicular tissue were made from material that had been embedded, sectioned, and stained according to standard methods. Those who reported 54 as the diploid number, with the exception of Ahmed, made their observations on the amnion. This tissue is thin enough to permit the direct study of whole cells without the necessity of embedding and sectioning.

To establish the exact number of chromosomes in a species a detailed morphological analysis of the chromosome complex is of primary importance. Since there is little agreement as to the morphology of the various chromosomes as well as disagreement as to the number present in the germinal tissue in sheep, a study was begun to ascertain the chromosome complex of germ cells by using some of the modern techniques.

*The author wishes to express his appreciation to Doctor B. L. Warwick for his help in obtaining the material for this study.



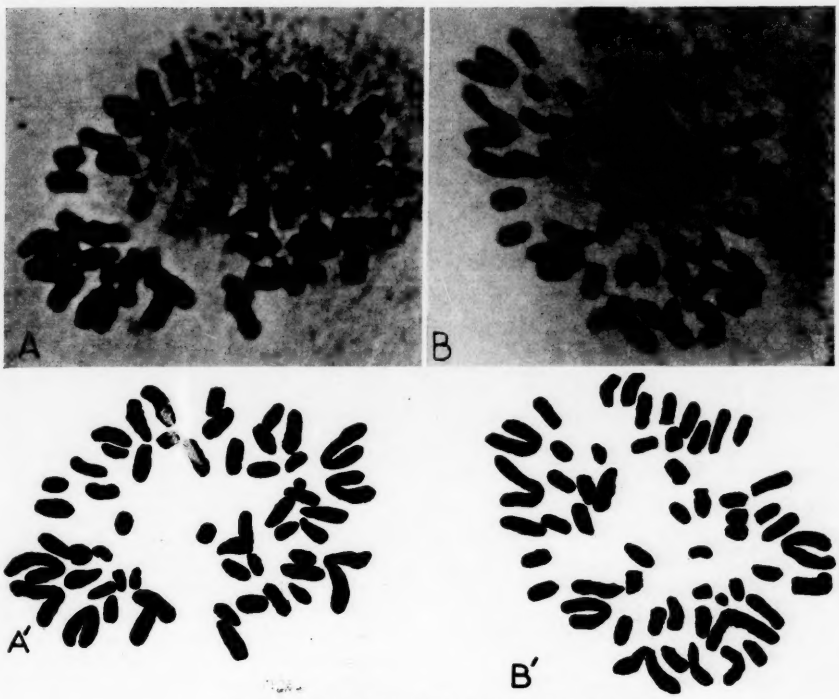
TWENTY-SEVEN PAIRS OF CHROMOSOMES

Figure 5

Aceto-carmine preparations of spermatogonial metaphases of sheep, showing 54 chromosomes. Note six large V-shaped chromosomes and one small sphere in each cell. There is reason to believe that this is the heteromorphic sex-chromosome (*Y*-chromosome). *A'-B'* are camera lucida drawings of the photomicrograph (*A-B*), × 2100.

Material and Technique

Testicular material was obtained from several young Rambouillet rams at about the time they reached sexual maturity. The tissue was obtained before the testis was removed from the animal and small pieces were placed immediately in the fixing solutions where they were teased into pieces small enough for rapid fixation. The tissue was fixed in: (1) 45% acetic acid, (2) Carnoy's fluid at room temperature, and (3) Allen's B-15 at 37° Centigrade. The part that was fixed in Allen's B-15 was subsequently embedded, sectioned and stained with Heidenhain's iron-hematoxlyn. The material that was fixed in Carnoy's (6:3:1) fluid was changed to 45% acetic acid after an hour and finally stored in acetic alcohol. By allowing the tissue to remain in the Carnoy's fluid for only a short time, undue hardening was avoided. The part that was fixed in acetic acid was also stored in acetic alcohol. Small pieces of testis were placed in aceto-carmine and the tubules, which in animals of this age can be easily separated from the interstitial tissue, were dissected free and mounted on a slide. Tissue treated in this way spreads easily and excellent preparations were obtained. The best preparations were found in the tissue fixed in 45% acetic acid. Use of the aceto-carmine method for



TWO OTHER SPERMATOGONIAL PLATES

Figure 6

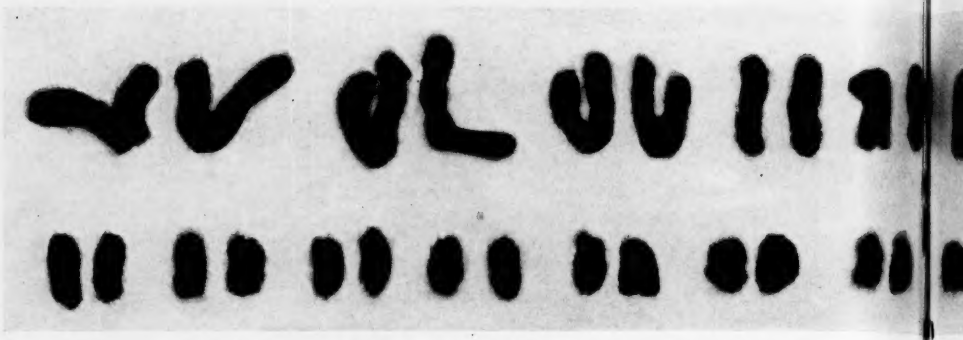
Material similar to Figure 5, showing additional figures with 54 chromosomes. The difference in chromosome number reported by various workers is probably due to identifying some of all of the six V-shaped chromosomes as two rods.

mammalian chromosomes was described by Painter[9] and since this method, with slight modifications, has proven far superior to any other method tried, it was used almost exclusively in this study.

Observations

By examining testicular material from lambs of various ages, it has been established that the best time for obtaining cytological material is the period when the animal has just attained sexual maturity. This period is characterized by the presence of very few spermatozoa in the epididymis and tubules. Such a stage can generally be recognized in domestic sheep by gross examination of the testes externally, i.e., noting especially the size of the testis and the firmness of the epididymis. Not only is the process of spermatogenesis at a high peak at this time, furnishing numerous mitotic figures, but the tubules are not crowded with spermatozoa and spermatids which obstruct observations, as is the case in older animals.

Chromosome counts were made on a large number of spermatogonial cells (more than 65). Many observations were made on cells in which there occurred very little over-lying or touching of chromosomes, as can be seen by the photomicrographs and drawings; and frequently all the chromosomes were in approximately the same optical plane. Thus there seems to be little chance for misinterpretation. The chromosome counts consistently gave 54 as the diploid



CHROMOSOMES OF SHEEP

Figure 7

Photomicrograph of the chromosomes of a spermatogonial metaphase arranged according to size and in possibly homologous pairs. The heteromorphic pair of chromosomes (*X-Y*) is the last in the series (lower right). This plate is made up by cutting apart and rephotographing the chromosomes shown in Figure 6*B*.

number (Figures 5 and 6). Metaphase plates of the primary spermatocytes contained 27 chromosomes (Figure 9).

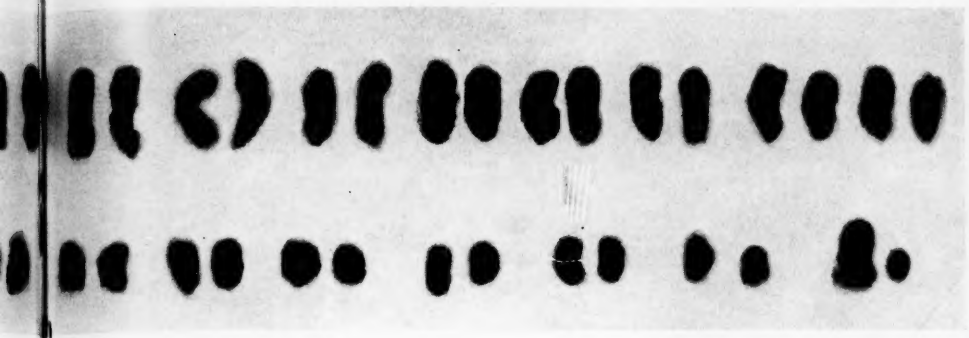
Morphologically the chromosomes can be classified as large V's, long rods, short rods, bent rods, and a sphere. With the exception of the six large V's, the chromosome complex in sheep exhibits a series of chromosomes grading gradually in size from the long rods to the sphere. The long rods approximate in size the arms of the large V-shaped chromosome.

In the spermatogonial metaphase three pairs of large V-shaped chromosomes can be distinguished individually by the comparative lengths of the arms (Figure 5*B*). One pair has one arm that is only about two-thirds the length of the longer. In the second pair, the right and left arms are slightly unequal in length. The third pair is somewhat smaller than the others and each arm is nearly equal length. In the prophase, these three pairs can be distinguished from any of the other twenty-four by their much greater length (Figure 8). During anaphase of the first maturation division they can be identified not only by their greater size but also by differences in their configurations resulting from the position of their spindle attachments.

The 43 rod-shaped chromosomes range in size from 1.5 to 4 microns in length and the smallest of these may sometimes appear spherical in shape. There are also two pairs of chromosomes of intermediate size which have the form of bent rods. One chromosome is readily recognized as being smaller than any other member of the group (Figures 5, 6 and 8). Since this small spherical element has no homologous mate among the other 53 chromosomes, it may be assumed to be the smaller member of a pair of heteromorphic chromosomes and also possibly one of the sex chromosomes. The identification of the larger member of this pair of heteromorphic chromosomes in the spermatogonial cells is very difficult since this member is similar in size to a number of others in the group. However, observations on the anaphase of the first maturation divisions give evidence that this small chromosome is paired with one of the medium size rods.

Discussion

The variation in the number of chromosomes in sheep as reported by various authors is partly, if not entirely, the result of differences in the interpretation of the 6 large V-shaped chromosomes. When these are considered to be 12 rods according to the interpretation given them by Butarin,[4] Novikov,[7] and Bruce,[3]

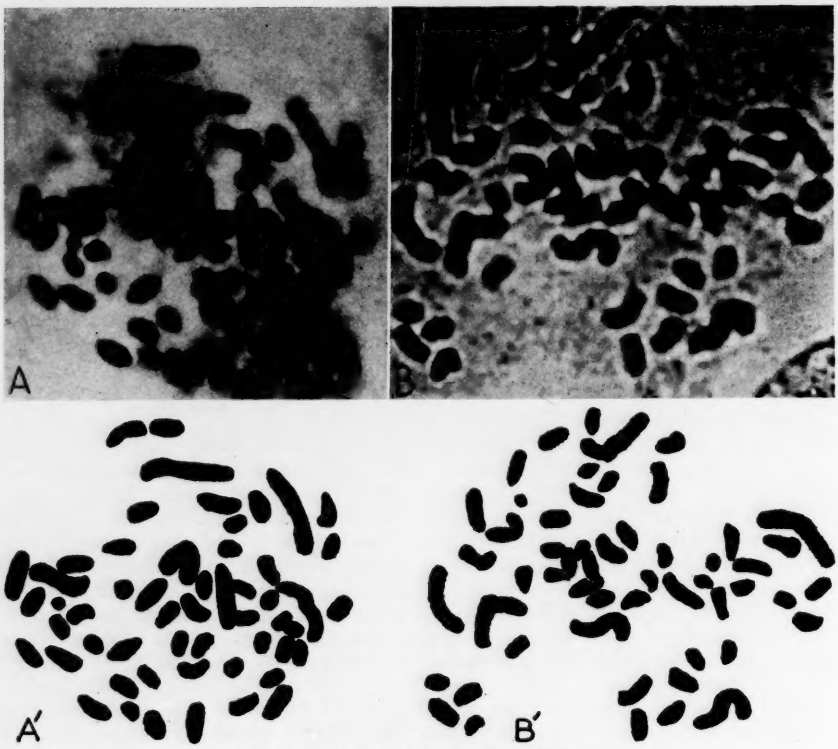


the chromosome number is found to be 60. Krallinger[6] recognized large V-shaped chromosomes and illustrated one in each of the two spermatogonial cells which he figured. These two cells were represented as having 58 and 56 chromosomes. He was aware that several large V's were present since he states in his paper that "Bemerkenswert ist, dass das Hausschaf einige grössere, V-förmige Chromosomen besitzt..." His conclusion that 60 chromosomes was the most likely number was the result of his finding what he interpreted as 30 components in the maturation divisions. Although Ahmed recognized only three large V-shaped chromosomes, he described 54 chromosomes in the spermatogonial cells. His observations, however, were chiefly concerned with the maturation divisions in which he consistently found 27 pairs of chromosomes.

In drawings of the spermatogonial metaphase by various workers (Krallinger, fig. 10, a. and b; Butarin, fig. 1; Bruce, fig. 11), several apparently V-shaped chromosomes which the authors have figured as two rods can be identified. They have interpreted these as two rods which are close together with their proximal ends touching. However, such a conclusion is likely since the identity of the six large V-shaped chromosomes in a single cell is difficult to establish unless the arms of all the chromosomes lie in approximately the same plane. In sectioned material the likelihood of finding such a cell is very slight. With the method used in this investigation numerous cells were observed in which the six V's were readily discernible but not a single figure was found which permitted the interpretation of any of these putative V's as rods with their proximal ends in contact. The interpretation of them as V-shaped chromosomes is also supported by the observations during prophase of six chromosomes approximately twice as large as any others. Therefore, it is highly probable that the elements in question are in reality six V-shaped chromosomes rather than twelve rods arranged in such a manner (terminal apposition of two rods) to produce apparent V's. With the identification of these six chromosomes in question, it now seems to be fairly conclusively established that the diploid chromosome number for domestic sheep is 54, at least for the Merinos (including Rambouillet). This is in agreement with the number reported by Shiwago,[10] Berry,[2] and Ahmed.[1]

The Sex-Chromosomes

A pair of heteromorphic chromosomes in sheep has been described by Bruce, Butarin, Shiwago, and Ahmed, but not all are agreed as to which members of the group comprise this heteromorphic pair. Bruce, Butarin, and Shiwago have figured the *X*-chromosome (the larger member of the heteromorphic pair) as belonging to the larger of the medium-sized group. The *Y*-chromosome

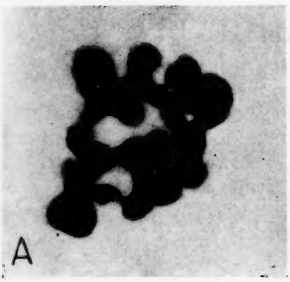


EARLIER STAGES IN DIVISION

Figure 8

Aceto-carmine preparations of spermatogonial prophases of sheep showing 54 chromosomes. The six largest chromosomes can be readily identified. The photomicrographs (*A-B*) are × 2100. *A′* and *B′* are camera lucida drawings of cells *A* and *B*.

according to Shiwago and to Bruce is a member of the smaller group and according to Butarin it is the smallest chromosome. Ahmed described the *X*-chromosome as a large V-shaped chromosome with a median centromere and the *Y* as one of the larger rods with a subterminal centromere. He also identified two different configurations of the *XY* at diakinesis and metaphase. These two configurations (symmetrical and asymmetrical sex bivalents) are described as being determined by the position of the pairing segment of the *X* and *Y* with respect to the centromere and the localization of the chiasmata in the pairing segment. Notwithstanding Ahmed's detailed analysis of chiasmata formation between segments of the sex chromosomes, there is no evidence in the present study to support his contention that the *X* is a large unpaired V-shaped chromosome. Contrary to his findings, there are three pairs of large V-shaped chromosomes and none of these form a heteromorphic pair. However, a heteromorphic pair of chromosomes is present which is composed of the smallest member of the complex and one of the medium-sized chromosomes.



CHROMOSOMES PAIRED

Figure 9

Metaphase of first spermatocyte of sheep showing 27 pairs of chromosomes. Each of the dark objects shown more clearly in the camera lucida drawing (*A'*) represents a pair of chromosomes. Note the three pairs of large chromosomes.

Observations on the chromosome complex in sheep by the various workers have included three breed groups, two wild species, and hybrids of these wild species with domestic breeds. It is possible that some of these groups may be dissimilar in their chromosome complex but this does not seem to be the logical explanation for the different numbers reported by Krallinger, Shiwago, Bruce, and Berry since they all made observations on the Merinos (including Rambouillet).

The present work has established a basis for a comparison of the chromosome number and morphology in different groups of sheep. Such a comparison should be of value in classification of sheep and their near relatives.

Summary and Conclusions

1. The testicular material most favorable for study of mitotic figures may be obtained from sheep at the time when they are attaining sexual maturity.

2. The aceto-carmine technique greatly enhanced the observations on the testicular tissue.

3. The diploid chromosome number in Rambouillet sheep is 54.

4. Six large V-shaped chromosomes are distinguishable in the chromosome complex and the evidence for the presence of these six V's furnish the basis for establishing the chromosome number in the spermatogonial cells of sheep.

5. The presence of one chromosome smaller than any other member in the complex gives evidence for a heteromorphic pair of chromosomes in sheep.

Literature Cited

1. Ahmed, I. A. The structure and behavior of the chromosomes of the sheep during mitosis and meiosis. *Proc. Royal Soc. Edinburgh* 60:260-270. 1940.

2. Berry, R. O. Comparative studies on the chromosome numbers in sheep, goat, and sheep × goat hybrids. *Jour. Hered.* 29:343-350. 1938.

3. Bruce, Harold A. The spermatogenetic history in sheep. Ph.D. Thesis, University of Pittsburgh Library. 1935.

4. Butarin, N. S. Chromozomnyi kompleks arhara (*Ovis poli karelini* Serv.) i kurdjucnogo barana. (The chromosome complex of the arhar and the fat-rumped sheep.) *Trudy Kirgiz. kompl. Eksp.* 4(3):77-80, 1933-1934 (cited from *Animal Breeding Abstracts* 4(1)45. 1935).

5. ————. The chromosome complex of Arkhar (*O. polii karelini* Serv.), kurdiuchny ram (*Ovis steato pyga*) and their F_1-hybrid. *C. R. (Dokl.) Acad. Sci., U.R.S.S., N.S.* 4: 287-290. 1935.

6. Krallinger, H. F. Cytologische Studien in einigen Haussäugetieren. *Wiss. Arch. f. Landwirtsch. Abt. B. Arch. f. Tierernähr. u. Tierzucht.* 5:127-187. 1931.

7. Novikov, I. I. Chromosomes in the spermatogenesis of interspecific hybrids of the European Mouflon and the domestic sheep (Merino). *C. R. (Dokl.) Acad. Sci., U.R. S.S., N.S.* 4:93-94. 1935.

8. Pachakadze, G. M. A new data about the chromosome number in domestic sheep. *C. R. (Dokl.) Acad. Sci., U.R.S.S., N.S.* 3: 333-334. 1936.

9 Painter, T. S. An aceto-carmine method for bird and mammalian chromosomes. *Science* 90:307-308. 1939.

10. Shiwago, P. I. Karyotypische Studien an Ungulaten. I. Über die Chromosomenkomplexe der Schafe und Ziegen. *Zeit. f. Zellforsch. u. mikro. Anat.* 13:511-522. 1931.

11. Wodsedalek, J. R. Studies on the cells of sheep with reference to spermatogenesis, oögenesis, and sex determination. *Anat. Rec.* 23:103. 1922.

TWINNING IN CHICK EMBRYOS

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IN a recent issue of this JOURNAL, Professor H. H. Newman[4] described and illustrated some very beautiful specimens of twins and triplets in chick embryos. In discussing the origin of these abnormalities he did not refer to the recent work of Wetzel, Gräper, Pasteels, Jacobson and others on the morphogenetic movements occurring during the early stages of chick development, nor to the recent experimental work on the developmental mechanics of the avian embryo. Advances in our knowledge in these two fields make it possible to offer rather more definite suggestions as to the formation of the twins than Professor Newman allowed himself.

During the two phases of gastrulation in the chick (formation of endoderm and then of mesoderm) there are extensive movements along the longitudinal axis of the embryo. There is first a movement of the invaginated endoderm from the posterior towards the anterior. This moving endoderm induces the formation of a primitive streak in the epiblast lying above it (Waddington[6]), and during the formation of the streak, the epiblast also moves forward from the posterior towards the anterior. By the time the streak is fully formed, a transverse movement of epiblast from the sides towards the streak is under way, and this continues as long as the mesoderm is being given off. From the anterior end of the fully formed streak there is a forward movement of the head process, which develops into the most anterior part of the notochord. But, from the fully formed streak stage onwards the main longitudinal movement is directed backwards, causing an elongation of the presumptive notochord and neural plate into their final long narrow shapes.

Split Axes

In a series of papers, I have reported a number of experiments performed during these stages on chick embryos explanted into tissue culture. In the course of these, a number of phenomena have come to light which have a bearing on the mechanism of twin formation. There is in the first place no doubt that, as Newman maintains, the occurrence of two or more loci of endoderm invagination might lead to the formation of two complete axes.[6] The questions which require discussion are, firstly, the "splitting" of axes, and secondly the fusion of embryonic rudiments.

Newman does not describe exactly what he means by the splitting of an axis. It seems, however, difficult to conceive of it as the separation of a fully formed primitive streak into two longitudinal halves which are then moved laterally away from each other; there is no obvious mechanism by which such a thing could occur, nor do we know of anything which could fill up the hole which would be left between them. On the other hand, it is easy to imagine one of the longitudinal streaming movements being impeded and split into two diverging streams by an obstacle in its course, and it is to mechanisms of this kind that we must look for an explanation of splitting of an axis.

In the *in vitro* experiments there have been no cases of splitting of the endoderm stream by an impediment in its course. Twiesselmann[5] has, however, described cases of anterior forking of the embryonic axis obtained by electrolytic injury to the unincubated blastoderm, and it is probable that such effects are to be interpreted as the results of splitting of the invaginating endoderm into divergent streams. They are strict-

ly comparable to Newman's case 1, illustrated in his Frontispiece *A*.[4]

Splitting of the forward movement at a slightly later stage, during the formation of the primitive streak, has occasionally been observed in the chick. It has been caused in tissue-cultured embryos by removing tissue from in front of the elongating streak[7] or by implanting material between the epiblast and hypoblast in this region.[1,2,3] In these cases the axis has forked on each side of the obstruction. The experiments were made at fairly late stages, and the forking affected only the anterior region of the embryo. The two separate branches of the axis each include only one half of the normal axis material, and if two complete heads are to develop, regulation must occur. In the experimental cases this regulation was slight, although somewhat better when the splitting was caused by an implant between the germ-layers than it was when a piece of tissue had been removed and a hole left. The cases figured by Newman which might be interpreted as a forking occurring during the forward movement of the streak also involve only incomplete regulation (cases 3 and 4, Frontispiece *C* and *D*).[4] One would expect to find that in general the more posteriorly, that is to say the earlier, the forking takes place, the more complete is the regulation into two perfect heads.

The greater number of Newman's cases show a posterior forking. There are two possible ways in which these might be explained. Either there have been two invaginations of endoderm which have been so placed that the primitive streaks have collided during their forward advance, or the backward movement of the streak in the neural plate stages has been impeded and split. Newman points out that certain of his cases (Nos. 6, 7 and 8) are certainly the result of the collision of two originally separate axes, but he suggests that others (Nos. 5 and 10 and 11) are due to splitting. Now even in the latter cases the two posterior branches are both quite complete, and it is very difficult to believe that this could be so if the forking was due to a splitting of the posterior movement. A forking at this time can only lead to the divergence of part of the retreating tissues to one side of the main body of the primitive streak. Numerous experiments have been made in which anterior parts of the streak have been transplanted into sites in the blastoderm, and it has been found that these grafts elongate backwards, just as the diverted branch in a posteriorly forked streak must do; but in all cases the grafted fragments form only part of an axis. They do not regulate completely enough to present pictures anything like those figured by Newman. Several examples will be found in Waddington and Schmidt,[8] (e.g. cases 32-135, 32-188, 32-136). It seems very doubtful, therefore, whether splitting of the backward moving stream can be an explanation of twins with two perfectly developed posterior ends.

Fusion and Collision

The alternative explanation is that these cases are, like those mentioned above, due to the occurrence of two separate endoderm invaginations which later fuse in the anterior region. Newman views this explanation with disfavor on the grounds that the collision of two axes always leads to the development of distorted heads. In one of his cases under discussion (case 10) the regulation is indeed somewhat imperfect, and Newman does not feel able to reject the explanation in terms of double invagination. In case 11, however, the head is single and well formed. Evidence from the *in vitro* experiments strongly suggests that this is no ground for dismissing the possibility that a fusion has occurred. Even as late as the end of the primitive streak stage, two nearby axes can unite to a very considerable extent; the matter was discussed in Waddington and Schmidt[8] and several examples are given there. Less conclusive evidence is available as to earlier fusions, owing to the technical difficulty of keeping the embryos

alive long enough. One would, however, expect regulation to be better at earlier stages than at later, and the fusion of colliding primitive streaks figured in Waddington[6] (cases 32-95 and 742), certainly looks complete enough to allow full regulation to occur. On the other hand, an experimental case of collision of primitive streaks (No. 716) did give a distorted and unregulated pair of heads.

It is probable that the degree to which two colliding streaks fuse and regulate, or remain separate and distort one another, depends on the exact way they come together; one would expect head-on collisions to be less easily smoothed out than mere convergencies at comparatively small angles, such as that seen in Newman's case 11. The almost complete suppression of head-formation in his cases 7 and 8, where a head-on collision has certainly occurred, suggests that in such circumstances the protrusion of the head process forward from the primitive pit has been prevented. In case 11, where the two axes are united at a smallish angle some distance behind the primitive pit level, there has been no reason why the anterior parts of the two streaks should not fuse and give rise to a single head process and thus to a single head. There is therefore no cause to consider this example as a case of splitting and not of fusion.

The same is probably true of case 5. This is a triple monster, in which two of the components are united posteriorly. They must in fact have been due to a splitting of the forward movement of their axis, in the manner discussed above. One branch of this axis comes, still further anteriorly, into the neighborhood of the third axis, and these two are then bent sharply through about 60°. This bend is at about the level of the ears, that is to say, at the level corresponding to the primitive pit. The parts which are bent are therefore the parts derived from the forward growth of the head process, and the apppearances can be quite well accounted for if one supposes that in this case, after collision of two primitive streaks, the head processes did not, as usual in such cases, suppress each other, but were both bent in such a way that they could both form normally. Newman's explanation is a splitting of an axis to form the two major posteriorly diverging axes, followed by a second split to form the minor anterior forking of one of these axes. It is argued here that the first postulated split could not give the two complete posterior ends actually found; and the second split is quite unacceptable, since there is no way of forming an anterior forking subsequent to a posterior splitting. The present suggestion is, therefore a double invagination, an anterior forking of one axis, subsequent approach of the two primitive pits of the main axes and mutual bending of the two head processes.

Summary and Conclusions

It seems, then, that all cases of posteriorly forked twins can be accounted for better as the results of double invagination than as splittings. On the other hand, anterior forkings are probable due to splitting of the invaginating endoderm or of the elongating primitive streak.

✦

How Long Will Weed Seeds Live?

A 60-year report on the germination of weed seeds buried in 1879 by Dr. W. J. Beal of Michigan State College showed evening primrose and mullin growing well after 60 years. Curled dock still grows. Mustard grew up to 50 years; peppergrass and pigweed to 40 years. In the test a mixture of 20 kinds of weed seeds were placed in bottles and buried 18 inches below the surface in sandy soil. Every 5 years one bottle was taken up and the seeds planted. In 1920 the period was extended to 10 years.—*Science Digest.*

THE INHERITANCE OF PARALYSED HIND LEGS, SCROTAL HERNIA AND ATRESIA ANI IN PIGS

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THIS paper presents some of the breeding experiments at the pig breeding station, the Agricultural College of Norway, Aas.

Paralysed Hind Legs

Paralysed hind legs probably caused by a recessive sublethal factor were reported by Wriedt from a herd of Norwegian Landrace. Animals descending from this herd were purchased and proved to be carriers. The findings were in perfect accordance with the hypothesis of Wriedt. Matings of heterozygous animals had 21 normals and 7 paralysed. Affected pigs could not rise and walk, but were able to crawl by means of the forelegs which were not so strongly affected as the hind legs. The affected pigs were inclined to lie always on the right side. If laid on the left side they managed to crawl forward, but came to rest on the usual side. The affected pigs died a few days after birth in spite of all possible care. Probably some internal anomalies were concomitant. Figure 10 is a photograph of an affected pig.

Koroveckja[4] has reported from Russia a hereditary anomaly, which in many respects resembles that described above. The character was called recumbent. Histological examinations revealed a degenerative atrophy of the motor cells. Litters containing affected piglings had 19.5 per cent affected. This indicates a deficiency in the number of affected.

If the factor is a monogenic recessive, we should rather expect a little above 25 per cent in litters containing affected as the limited number in each litter will tend to eliminate some litters containing only normals. The expected proportion in litters containing affected pigs is found by the formula:

$$\frac{p.\ \Sigma\ xn}{\Sigma\ xn\ [1-(1-p)^x]}$$

when x stands for the number of pigs in each litter, n for the number of litters with x pigs and p for the expected proportion of affected pigs.

Hallqvist[3] has reported a lethal anomaly named bent legs, which primarily affected the forelegs, from the Large White Breed in Sweden. Hallqvist maintains that bent legs is a complete parallel to the case found by Roberts in sheep. Figure 11*B* presents a pig with bent legs.

From herds of German Landrace a sublethal anomaly called thick legs has been reported. The forelegs were thick and could not be stretched. It was caused by disturbance of the circulatory system and resembled elephantiasis. The case is reported latest by Carstens and co-workers[2] in 1937. Figure 11*A* shows the variable manifestation of thick legs. The data suggest a monogenic recessive.

The two last mentioned characters affect primarily the forelegs and differ in many other respects the two first mentioned characters.

Scrotal Hernia

Warwick[5,6] suggests a digenic recessive mode of inheritance for this defect. His experiments with selection for hernia suggest in my opinion rather a type of incomplete dominance.

Koroveckaja[4] reports that litters containing herniated piglings had 20 per cent affected and the sex proportion in these litters was 57.1 per cent males, which is a considerable excess of males. Koroveckaja suggests that homozygous females die as embryos. This explanation is probably not correct. The deviation is obviously caused by the grouping of litters. A classification of litters in a group containing affected pigs cannot give an unbiased estimation of the underlying segregation ratio and the sex ratio. Only the males are affected and the number of males in each litter averages between four and five. If the segrega-

PARALYSED LEGS
Figure 10

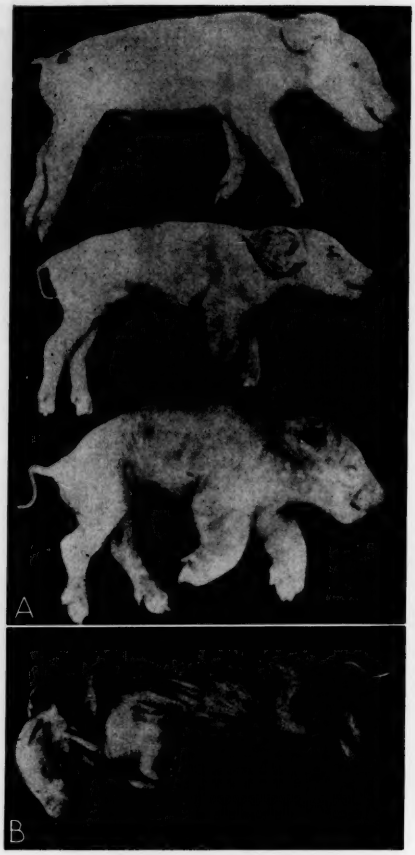
Female pig No. 100 with paralysed hind legs. Born August 6, 1932. The pig is alive and lying on the right side. Pig Breeding Station, Aas.

tion ratio in each litter be 15 : 1, litters containing affected piglings would give 23 per cent affected males in a litter of five males. With the same litter size the same classification of litters would give 23 per cent affected males, when the distribution of scrotal hernia was quite at random and not hereditary with a frequency of 15 : 1. The excess of males is obviously caused by the fact that litters with a large number of males have a greater probability to reveal one or more cases of hernia.

At the Pig Breeding Station some cases of scrotal hernia have appeared. Most of them seem to be sporadic, although in a few cases a genetic basis may be assumed. In a total of 414 litters the litter average was 3.95 (46.9 per cent) ♀ ♀ and 4.48 (53.1 per cent) ♂ ♂. Of the females, 0.61 per cent were umbilically herniated; and of the males 0.65 per cent. Inguinally herniated females constituted only 0.37 per cent of the total. Scrotally herniated males totalled 1.99 per cent.

The segregation ratio in 31 litters with average of 5.8 males (57.14 per cent) containing 37 cases of scrotal hernia was 20.6 per cent. This percentage is expected in litters of 5.8 males and a segregation ratio of 6.25 per cent, and 20 per cent is the expected ratio for the same litter size when scrotal hernia is distributed at random.

As in the Russian report a high excess

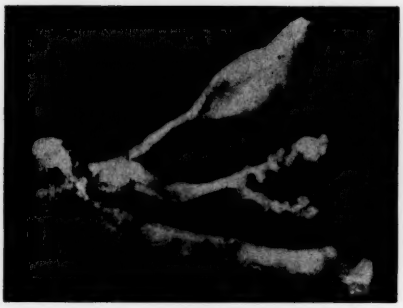


"THICK LEGS" AND "BENT LEGS"
Figure 11

A—Normal pig and two pigs with "thick legs" in different manifestations. From Walther and collab. 1932. *B*—Pig with "bent legs" (from Hallqvist, 1933).

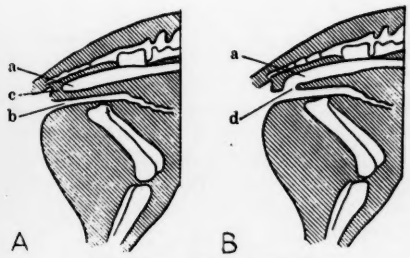
of males in litters containing affected pigs is noteworthy, but the excess is caused by the grouping.

In order to eliminate the differential fertility in the sows we have grouped 110 litters of 24 sows which had had litters containing affected and litters with no case of scrotal hernia, and examined the two groups separately. In 83 litters without affected a sex ratio of 51.28 per cent males was found, and in



AVIAN ANATOMY IN SWINE
Figure 12

Rectum, uterus, sheath, urethra and bladder of female pig No. 180 with cloaca, born Jan. 25, 1935, Pig Breeding Station, Aas.



DETAILS OF DEFECT
Figure 13

Longitudinal section of female pigs with atresia ani, right without opening of rectum, left with cloaca (from Carstens and co-workers, 1937).

27 litters with affected pigs a sex ratio of 57.93 per cent was found. The expected sex ratio when all litters had the same probability of scrotal hernia was 56.14 per cent. The deviation from the found ratio is not enough to justify the Russian hypothesis, that homozygous females die during the foetal period. The expected number of males per litter was found by the following formula:

$$\frac{\Sigma\, nx\,[1-(1-p)^x]}{\Sigma\, n\,[1-(1-p)^x]}$$

where x stands for the number of males in a litter, n for the number of litters with x males and p for the probability of scrotal hernia.

Probably very few of the cases had a genetic basis. A single boar was an exception to the rule and indicated an incomplete dominant mode of inheritance with a manifestation ratio probably under 50 per cent.

It should be mentioned that Wriedt has reported in the pig a type of heredity *umbilical* hernia of an undoubtedly dominant mode of inheritance.

Atresia ani

Descriptions of sporadic cases of atresia ani are often found. The malformation is different in sows and boars. Typical in the boars is the closed rectum. After a couple of days the affected pigs die owing to obstruction. In the sows the anus is closed but usually an opening is found in the ventral side of the rectum with a communication to the sheath, resulting in a type of cloaca. These sows can live and some survive to maturity and are fertile. Cases of hereditary origin are reported from Germany, latest by Carstens and co-workers.[2] Figure 13 is an outlined longitudinal section of affected females.

The mode of inheritance was irregular and great deviations from the segrega-

TABLE I. Offspring of sows with cloaca.

Sire	Sow No. 136 Normals	Sow No. 136 A. ani	Sow No. 137 Normals	Sow No. 137 A. ani	Percentage of A. ani
Jarl	2	3	9	1	26.7
Frikk	6	1	15	3	16.0
Aros	4	0	12	0	0

TABLE II. Offspring of sows mated to both Jarl and Frikk which had affected pigs with either of them.

Sows Giving A. ani with	Sows	Jarl Normals	Jarl A. ani	Frikk Normals	Frikk A. ani
Jarl only	4	28	5	37	0
Frikk only	1	21	0	23	2
Jarl and Frikk	3	24	13	34	7

tion of a monogenic recessive were found. In many respects the breeding results indicated a dominant mode of inheritance.

At the Pig Breeding Station, Aas, two boars of Large White were carriers of a factor causing atresia ani.

Photographs of three dissected pigs with atresia ani are presented as a supplementary document.*

The boars, Jarl and Frikk, were both apparently normal, but inherited atresia ani in a different manner. Jarl had 21.2 per cent atresia ani in litters containing affected and Frikk 14.3 per cent. Percentages of affected in the two sexes was equal. Two full sisters, daughters of Frikk, with cloaca grew up and were bred to Jarl, Frikk and an unrelated boar. The fertility was low, but we succeeded in getting four litters from each. The result is given in Table I.

Mated to Frikk, their father, the two sows had 16 per cent affected offspring but mated to Jarl they had 26.7 per cent. The number of offspring is not large enough to justify calculations of the segregation ratio, though it is clear that a monogenic mode of inheritance is out of the question. Sows giving affected pigs with both Jarl and Frikk averaged double the frequency of sows giving affected with only one of the boars.

It is impossible to set up a factor hypothesis, which excludes all other possible hypothesis. The number of offspring will always be limited and insufficient. The manifestation quota is probably low. I have suggested two pairs of factors but it is impossible to say if both, one, or neither of them are chiefly dominant. One of the factors or perhaps both, probably have originated by mutation in the offspring of the foundation animals, which were purchased in 1932.

When the mode of inheritance is so irregular, the purchasing of breeding animals would be almost impossible if the buyer required the animal to be free from genes causing the deleterious character. Even if the character is a clear-cut monogenic recessive, it is difficult to provide evidence of homozygosis of the normal allelomorph.

Blindness

A reported case of congenital blindness was examined. The breeder suspcted the case to be hereditary, as the blind pigs were all sired by the same boar, but an investigation revealed that the probable cause was a lack of vitamin *A* in the feed of the pregnant sows.

Literature Cited

1. Berge, S. Three hereditary anomalies in pigs. *Hereditas* 27:176-192. 1941.

2. Carstens, P., Wenzler, G. and Dürr, M. Einige Untersuchungsergebnisse über Vererbungserscheinungen beim Schwein. *Züchtungskunde* 12:205-217. 1937.

3. Hallqvist, C. Ein Fall von Letalfaktoren beim Schwein. *Hereditas* 18:215-224. 1933.

4. Koroveckaja, N. N. A study of some hereditary defects in the pig. Moskva, 1938. (Abstract in *Animal Breeding Abstracts* 7:232. 1939.)

5. Warwick, B. L. A study of hernia in swine. *University of Wisconsin Agr. Exp. Sta. Research Bulletin* 69. 1926.

6. ————. Breeding Experiments with sheep and swine. *Ohio Agr. Exp. Sta. Bull.* 480, Wooster, Ohio. 1937.

*Three photographs showing anatomical details of affected pigs have been issued by us through Auxiliary Publication, and may be obtained from the nonprofit Bibliofilm Service, American Documentation Institute, 2101 Constitution Ave., Washington, D. C., by ordering Document 1593, remitting 21 cents for copy in microfilm, readably enlarged full-size on reading machine or hand viewer, or 30 cents for copy in the form of paper photoprints readable without mechanical aid.

PROTOZOA IN BIOLOGICAL RESEARCH

A Review

THE protozoa have been very widely used for experiments on many biological problems. While there are quite a number of books dealing with these organisms, most of them are textbooks in which the results of experimental work are frequently obscured by the large amount of material on morphology and taxonomy. The present book* is primarily designed to bring together the more recent results of investigations in many phases of protozoology. For this purpose, a number of specialists have combined forces, each furnishing a chapter on the field in which he is particularly competent. The result is a very valuable reference work and summary of the present state of knowledge about these organisms.

Perhaps the simplest way to give an idea of the scope of the book is to list the titles of the various chapters and their authors.† The various authors include comprehensive bibliographies with their chapters, and there is a very detailed index to the whole book. As is inevitable in a work of this size, certain men who had originally planned to take part were unable to do so. This undoubtedly accounts for the omission of certain subjects among which the most noticeable to the geneticist will probably be the lack of any detailed account of the nuclear cytology of the protozoa save in so far as it is considered in special connections particularly in the chapter by Turner.

It is obvious from the list of chapters that much of the book deals with matters which are not of primary concern to the geneticist. This review will therefore be confined to comments on those chapters having a bearing on genetic problems.

Calkins in his chapter, *General Considerations,* first takes up certain generalizations regarding protozoan structure, distribution, and adaptation and reviews the early history of protozoology. He then turns to the very interesting problem of aging in the protozoa. Calkins' point of view is that aging or a tendency to become less vigorous with time is a fundamental property of the protoplasm of many if not all protozoa. This senescence can be overcome by rejuvenation through some major reorganization process such as conjugation, endomixis, etc. The work of a number of investigators, particularly of Calkins, has shown that under certain environmental conditions this is essentially what happens. However, some investigators have reported that clones can be maintained indefinitely without decline in the absence of any major reorganization process. Therefore, it seems doubtful whether the tendency to decline in vigor with time is a fundamental property of protozoan protoplasm rather than the result of unfavorable environmental conditions. Evidence on this question is reviewed in the chapters of Turner and of Jennings.

According to Calkins, rejuvenescence occurs to some extent at cell division as

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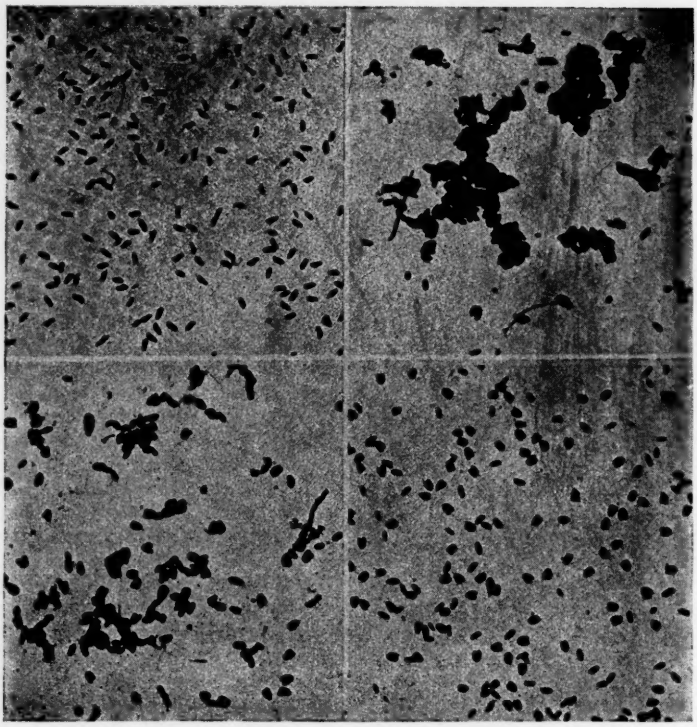
**Protozoa in Biological Research,* GARY N. CALKINS and FRANCES M. SUMMERS editors. Pp. 1148, $10.00, Columbia University Press, New York, 1941.

†The first chapter is *General Considerations* by Gary N. Calkins followed by *Some Physical Properties of the Protoplasm of the Protozoa* by H. W. Beams and R. L. King, *Cytoplasmic Inclusions* by Ronald F. MacLennan, *Fibrillar Systems* by C. V. Taylor, *Motor Responses in Unicellular Animals* by S. O. Mast, *Respiratory Metabolism* by Theodore Louis Jahn, *The Contractile Vacuole* by J. H. Weatherby, *The Technique and Significance of Control in Protozoan Culture* by George W. Kidder, *Food Requirements and Other Factors Influencing Growth of Protozoa in Pure Culture* by R. P. Hall, *The Growth of the Protozoa* by Oscar W. Richards, *The Life Cycle of the Protozoa* by Charles Atwood Kofoid, *Fertilization in Protozoa* by John P. Turner, *Endomixis* by Lorande Loss Woodruff, *Sexuality in Unicellular Organisms* by T. M. Sonneborn, *Inheritance in Protozoa* by H. S. Jennings, *The Protozoa in Connection with Morphogenetic Problems* by Frances M. Summers, *Certain Aspects of Pathogenicity of Protozoa* by Elery R. Becker, *The Immunology of the Parasitic Protozoa* by William H. Taliaferro, *Relationships between Certain Protozoa and Other Animals* by Harold Kirby, Jr., and *Organisms Living on and in Protozoa* by Harold Kirby, Jr.



MATING REACTIONS OF PARAMECIUM

Figure 14

The results of mixing animals of different mating types in *Paramecium bursaria*. Upper left, single mating type with individuals scattered singly. Upper right, clusters formed six minutes after mixture of different mating types. Lower left and right, stages in the breakdown of the clusters into conjugating pairs. (Figure 166 of *Protozoa in Biological Research*, from Jennings, 1939.)

well as at the major reorganization processes. He considers that such phenomena as chromatin elimination and various types of macronuclear and cytoplasmic reorganization are visible evidence of this. While these processes may well have a rejuvenating effect, there is to my knowledge no experimental evidence on this question. Until some is available, other interpretations are not excluded. For example, it seems quite possible to me that these processes are concerned with the reproduction of cell parts and not with their rejuvenation.

The nuclear changes that occur during the life histories of the protozoa are of considerable interest to those who wish to understand properly the genetic work with these organisms. The changes are discussed in the chapters by Kofoid, Turner, and Woodruff. The nuclear changes involved in the meiotic divisions are treated by Turner in particular. His chapter is especially to be commended in that it attempts to bring some uniformity into the rather confused picture of meiosis in the ciliates. There can be no question that more investigation is needed on this subject. Woodruff presents an excellent review of endomixis and other types of macronuclear reorganization in the ciliates and discusses

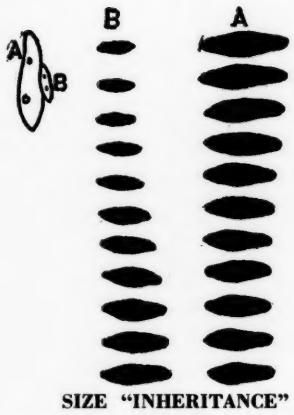


Figure 15

Change in size over the course of several asexual generations as a result of the conjugation of two animals, *A* and *B*, from races of *Paramecium caudatum* of very different size. The final size reached in the descendants of each is the same. (Figure 176, of *Protozoa in Biological Research.*)

the genetics of some of these processes.

Sonneborn's chapter deals primarily with the nature of the sexual differences in the two well analyzed cases in unicellular organisms, the work of Moewus and Hartmann on flagellates and of Sonneborn, Jennings, et al on ciliates. In the flagellates, Moewus has reported a series of physiological sex differences between morphologically alike gametes. The nature of these differences have led him to postulate two sexes, each of which is divisible into several subgroups of different sex strength. Recently, he has reported studies leading to a knowledge of the chemical basis of these sex differences. The interpretations in this work made by Moewus and Hartmann have followed the pattern of Hartmann's theories of sexuality. After a detailed review of this work, Sonneborn points out a number of serious criticisms of both the factual evidence and the interpretations. I heartily agree with Sonneborn that independent repetition of this work is desirable.

In the second part of the chapter, Sonneborn discusses the work on ciliates showing that the clones of several species can be divided into a series of mating types. In mixtures of animals of the same mating type, no conjugation occurs; but in mixtures of animals of different mating types, it does. Sonneborn discusses the mating type systems in the several species in which they have been studied and presents some evidence on the nature of the mating type differences. After a comparison of the various types of sex differences found in protozoa, he comes to the conclusion that it would be well "to abandon the concepts of male and female in unicellular organisms and to view sexual union as brought about by copulation-conditioning factors—." The reviewer agrees completely with this point of view.

Jennings' chapter is divided into sections on inheritance during uniparental or asexual reproduction and following biparental or sexual reproduction. In the first section, a variety of experimental results are brought together which indicate that though a group of individuals descended from one by vegetative reproduction are generally alike, differences do occur between them. Some of these differences may be inherited over quite a number of asexual generations. The physical basis for the inheritance of these differences cannot always be ascertained with certainty, but there seems reason to believe that they may be dependent on cytoplasmic inheritance of one sort or another.

The section of the chapter dealing with inheritance following biparental reproduction considers first, in some detail, the extensive work of Moewus on certain flagellates. Moewus reports the occurrence of a number of genes behaving essentially like those of higher organisms. Jennings points out that serious criticisms may be made of Moewus' work. I would go somewhat further and say that in view of the nature of these criticisms any evaluation of this work must await independent repetition.

The recent results on the inheritance of mating types in the ciliates is presented in some detail. These investigations have led to the discovery of the first definitely established gene in these organisms. Other evidence is more difficult

to interpret though it indicates that the macronucleus plays an important role in mating type determination. The nature of this role is not completely understood. Finally the evidence on cytoplasmic lag is presented showing that following a change in the nuclear constitution the cytoplasm is changed over the course of a number of asexual generations.

Some of the other chapters, particularly those by Becker and by Taliaferro contain material on strain specificity and similar phenomena of interest to the geneticist but none of these subjects have been investigated sufficiently from the point of view of genetics.

In general, *Protozoa in Biological Research* is a well written, well organized, authoritative summary of what has been accomplished by investigations on the protozoa. It should we available to all biologists who are interested in the contributions of protozoology to their science.

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A SPONTANEOUS TETRAPLOID SNAPDRAGON

(See Frontispiece, Page 242)

RONALD BAMFORD AND FRED B. WINKLER
University of Maryland

WHILE conducting experiments in hybridizing varieties of the snapdragon (*Antirrhinum majus* L.) the junior author observed a larger plant among one of the F_1 populations. These hybrids were the result of crossing the varieties Coates Yellow Perfection and Yellow Cheviot Maid. Over eight hundred seeds were produced and planted. Among this population two plants were finally observed which appeared different than the remainder. These plants were carefully examined and their differences are presented in the Frontispiece. The stems, inflorescences, leaves and individual flowers were larger (Frontispiece *A-A'*). When the epidermis was removed from the leaf and the pollen was examined differences were observed between the size of the stomata and the pollen grains of the two types (*B-B'*, *C-C'*). Smear preparations of both the root tips and flower buds were made and the chromosome number (*D-D'*) of the smaller was $2n=16$ in contrast to the larger which had a $2n=32$ chromosome complement. The larger tetraploid has since produced seeds upon selfing and in crosses with both the diploid parents. The nature of these offspring will not be known until later.

Ruttle and Nebel[2] reported the first tetraploid snapdragons but these were the result of colchicine treatment. They note that the tetraploid had "sturdier stems, larger, thicker somewhat pebbled leaves and larger flowers with a more ruffled corolla and somewhat deeper coloring than the corresponding diploid." This is a description of the situation in this tetraploid except that the leaves were not pebbled. Emsweller and Ruttle[1] have recently reported a similar case which was found by a Denver florist. The exact origin of this spontaneous tetraploid was not known. Colchicine tetraploids have also been reported by Straub.[3]

Literature Cited

1. EMSWELLER, S. L., and M. L. RUTTLE. Induced polyploidy in floriculture. *Amer. Nat.* (in press). 1941.

2. RUTTLE, M. L., and B. R. NEBEL. Cytogenetic results with colchicine. *Biol. Zentral.* 59:79-87. 1939.

3. STRAUB, J. Die Nachkommenshaft des tetraploiden *Antirrhinum majus* sippe 50. *Ber. d. Deut. Bot. Ges.* 59:110-113. 1941.

A SEX LINKED RECESSIVE FINGERPRINT PATTERN

J. FRANK WALKER

RADIAL AND ULNAR LOOPS

Figure 16

Pattern of right index fingers, showing two forms of loops encountered. The *radial loop*, on the left, is so called because it slopes toward the thumb and the radius. (The *print* slopes toward the left because it is reversed in making the impression.) The *ulnar loop*, on the right, is so-called because it slopes toward the elbow side of the hand. The radial loop on the *right index finger* appears to be inherited as a sex-linked recessive character.

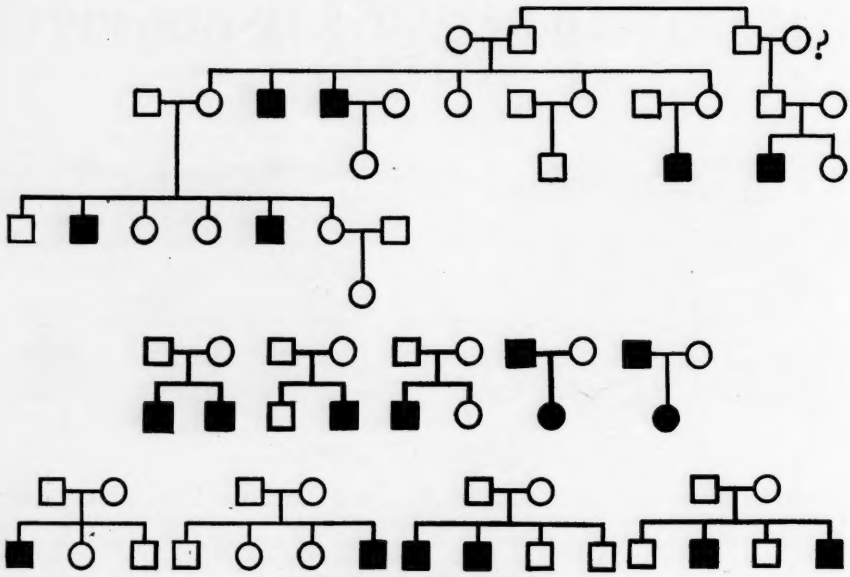
IT is generally agreed that fingerprint patterns have a hereditary basis, although the genetic principles involved are not completely understood. The writer has been interested in this field for some years, and offers the following data for critical inspection and test by other investigators. The material concerns *one* pattern, the radial loop, when found on the *right* index finger. It must be emphasized that left index finger pattern formations appear to follow a different type of transmission.

The radial loop is so called because the ridges have a downward slope from the direction of the little finger towards the thumb or radius bone of the forearm. The ulnar loop is distinguished from the radial in that the slope of the ridges is towards the little finger side. Examples of both are given in Figure 16, the radial being on the left. The reader easily will see that reversing the hands will, in turn, reverse the direction of ridge slope, and consequently, what appears as a radial loop on the right hand would be an ulnar loop on the left hand. It also should be stated that the rather uncommon radial central pocket loop must not be confused with the plain radial, although it appears occasionally on the same finger.

In the writer's collection of prints, a number (10) of matings have produced radials on the right index fingers of male offspring when neither parent exhibited the pattern in that position. In one family group, where the parents are deceased, two male children show radial loops. As will be noted in the pedigrees, these two males have sisters whose marriages have produced affected male children — in all probability, as carrier females. In no case do father and son both have the pattern (Figure 17).

A transmission such as shown, strongly suggests that a sex linked recessive gene is responsible. Further confirmation is afforded by the two matings producing affected daughters. Here, the fathers are also affected which is entirely in accord with the principles of sex linked recessive transmission.

Carrying the analysis still farther, the expected number of affected offspring per family (for a sex linked recessive characteristic when neither parent is affected) has been calculated against the observed number. The almost perfect



SEX-LINKED INHERITANCE

Figure 17

Pedigrees collected by the author in which the radial loop on the right index finger has been observed in parents or offspring. The first generation of the large pedigree on the first line was not living and the fingerprint patterns are unknown. In the other two generation pedigrees the transmission through "carrier" mothers to sons is consistently shown. In the case of direct transmission from fathers to daughters the mothers are assumed to be "carriers".

agreement between the two is shown in the table.

Two sets of figures are given for six sib families and two for totals. In one case, the two affected sons of deceased parents (whose patterns are actually unknown but assumed to be unaffected) are included. The first set gives only the offspring of known unaffected parents. In either case, the discrepancy is insignificant, being far less than the standard deviation.

While the population examined is relatively small, the evidence indicates that a sex linked recessive gene is probably responsible.

TABLE I. A Sex-Linked Recessive Fingerprint Pattern.

Known Family Size	Number of Families	MANIAS (Affected)		Variance
(s)	(a_s)	Observed	Expected	($a_s\sigma_s^2$)
1	1	1	1.00	.000
2	4	5	4.67	.489
3	1	1	1.89	.362
4	3	5	4.38	1.560
5	1	2	1.88	.775
	Totals	14	13.06	3.786
Discrepancy .94		Deviation 1.66		
6	2	4	3.84	1.561
	Totals	18*	14.88	3.848
Discrepancy 1.12		Deviation 1.86		

* See next to last paragraph of text.

POLYPLOID CASSAVA

Induced by Colchicine Treatment

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CASSAVA (*Manihot utilissima* Pohl) is of South American origin and possesses very rich deposits of starch in the roots, whose nourishing value was discovered long before the arrival of Columbus in the New World. The culture of cassava has extended today to the tropical and subtropical regions of all continents, as it was widely distributed shortly after the first Europeans arrived in America.

In Brazil the culture of cassava is very old and in the course of the recent development of policulture in the State of São Paulo, its culture has been so greatly extended as to play an important part in the economical balance of the State. The extraction of alcohol from cassava has become a promising industry in Brazil and the process of making bread from wheat mixed with cassava is being tried in our country.

Cassava is a very resistant plant, which is vegetatively propagated. Though a large number of varieties exist, only a few are being cultivated on a large scale. A selection of these varieties and the production of others by means of hybridization are important problems in cassava breeding. These studies are being carried out using such modern methods as those offered by cytogenetics.

In a previous paper[2] the author studied the mega- and microsporogenesis of this plant, verifying that in both cases the process follows, in general lines, the normal course established for the great majority of plants. The number of chromosomes was also determined for 37 varieties cultivated in different regions of the country (Deodoro, in the state of Rio de Janeiro; Piracicaba, in the state of São Paulo; and Divinopolis, in the State of Minas Gerais). Without exception, the $2n$ chromosome number was found to be 36 in root tips, with $n = 18$ in microsporogenesis.

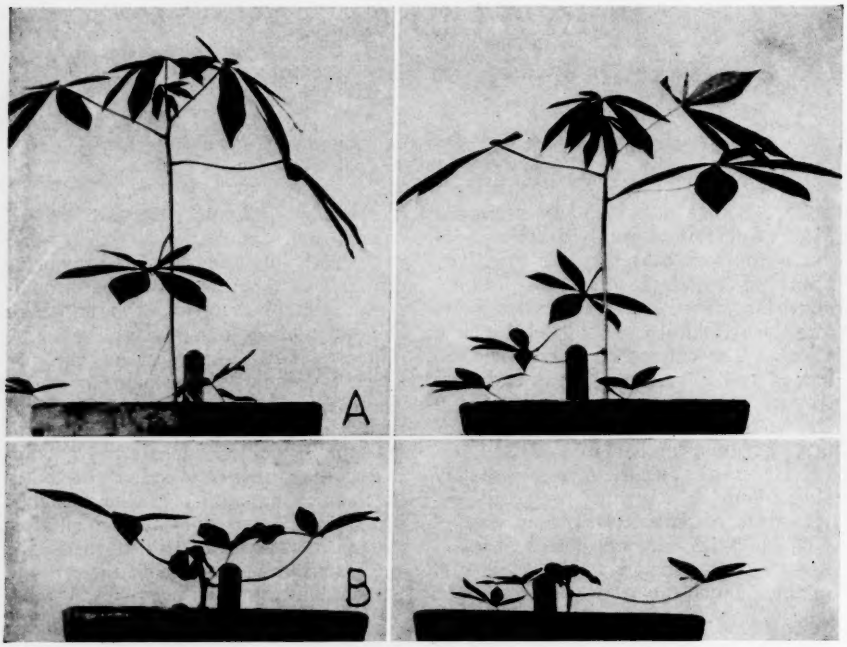
Up until this time I had the opportunity to determine the number of chromosomes of many other varieties, but there has not yet been found any plant of *M. utilissima* with a number of chromosomes larger or smaller than $2n = 36$. As a result of the study of meiosis[2] it was shown that the plants with 36 chromosomes should be considered as diploids although there is still a possibility of their being auto- or allopolyploids. These details may only be decided after a detailed analysis of wild forms of the genus and its relations with the types at present cultivated.

In modern plant breeding polyploid plants may be of value since they are often more productive and vigorous. Therefore it may also be expected that plants of cassava, with a number of chromosomes greater than 36 may produce roots with an increased starch content besides a greater total volume.

I have been able to verify a duplication of the number of chromosomes in a chimera spontaneously produced in the root-tips.[3] After the discovery by Blakeslee and Avery[1] of the effects of colchicine it was thought to apply also this alkaloid to cassava, hoping thus to get polyploid individuals.

Methods

The plants of cassava which were to be treated with colchicine were obtained from cuttings, according to the method used for the commercial propagation of this species. Seven-inch cuttings planted in pots develop in 30 days one or more shoots about seven inches long, the strongest of which was retained for the alkaloid application. Thus in this way 50 plants were prepared and colchicine was applied to 40 of them leaving the

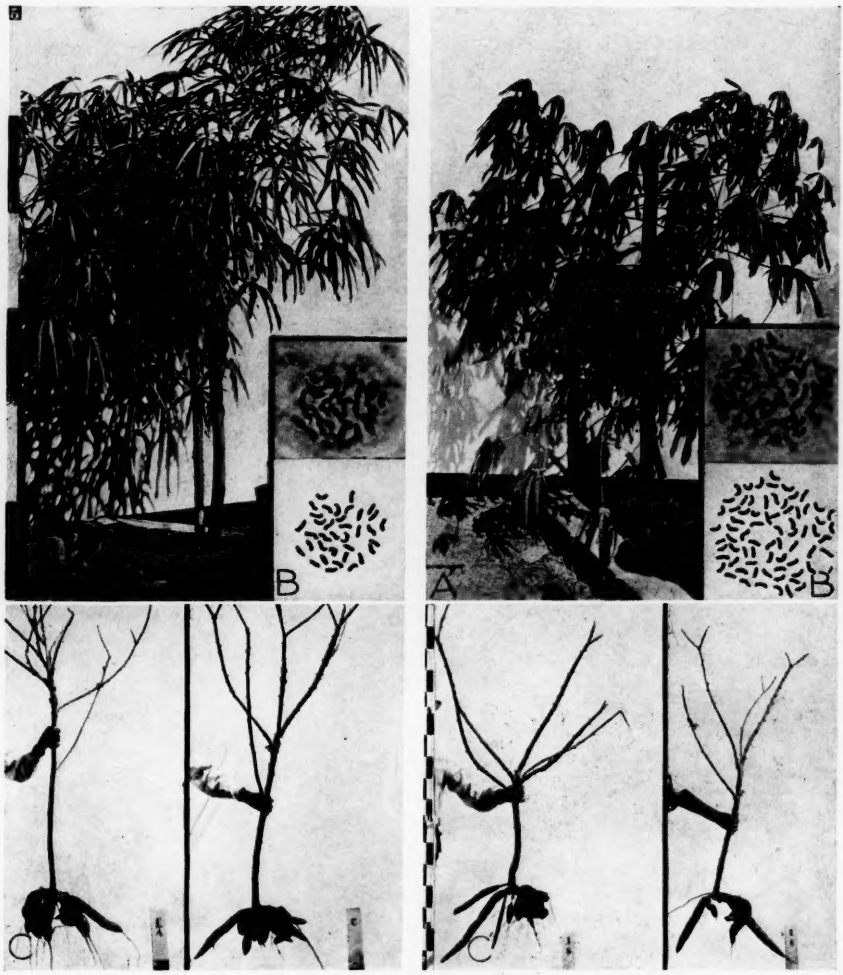


TREATMENT OF CASSAVA PLANTS WITH COLCHICINE

Figure 18

A week after finishing the treatment, the treated plants (*B*) were nearly paralyzed, whereas the control plants (*A*) continued to develop normally. Treatments consisted of keeping the growing point moist with a piece of cotton soaked in a solution of colchicine of either 1% or .5% strength.

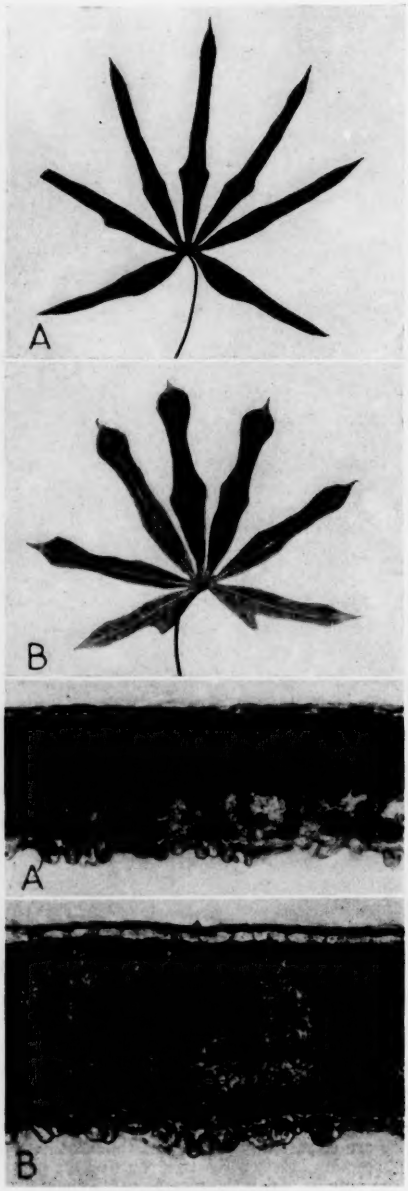
remaining 10 as controls. Two colchicine solutions were used, one of 0.5% and another of 1.0% and both were applied to the terminal part of the shoots by soaking a piece of cotton in the solutions and fixing it between the young leaves, touching the apical bud. These pieces of cotton were examined and moistened if necessary two or three times a day, to prevent their becoming dry. During the eight days of treatment the plants remained in the laboratory and were removed after that to the greenhouse where they stayed until transplanted into the experimental garden. The time during which a plant remained in the greenhouse was very variable, owing to the differences in their growing habit. The plants which received treatment became more or less paralyzed for a month, after which they began to develop very irregularly. The controls on the other hand grew so fast (Figure 18) that it was necessary to transplant them to the beds well before the treated plants. Since cassava plants were found to be very sensitive to reduction of light the plants could only be maintained in the greenhouse long enough for them to acquire a reasonable size and vigor which lessened the risk of loss by diseases and other hazards during the beginning of their development. It was necessary to examine the treated plants every day and to remove the many secondary shoots in order to prevent any competition and to force the development of the treated ones. From the 40 treated plants, 13 did not



TREATED AND NORMAL CASSAVA PLANTS

Figure 19

Six months old diploid control cassava plant (*A*) with 36 chromosomes, compared with (*A'*) a plant treated with 1% colchicine solution. This has the chromosome number of the top doubled ($4n = 72$), though the roots are diploid ($2n = 36$). The chromosomes (*B-B'*) are $\times$ 3000. The root development of two normal plants (*C*) is compared with two treated plants (*C'*). In the latter, while the roots are diploid, they are consistently longer and thinner than on control plants, showing a curious "stock and cion" reaction between the two parts of the plant. Abnormal development of the roots is caused by the pots in which the plants passed their first stages of development. The second roots of diploid plants are only slightly larger than the second roots of tetraploid plants. The production of $4n$ roots can only be studied after the plants obtained from the tetraploid cuttings have reached maturity at the end of two vegetative cycles, or 18 months.



LEAVES COMPARED

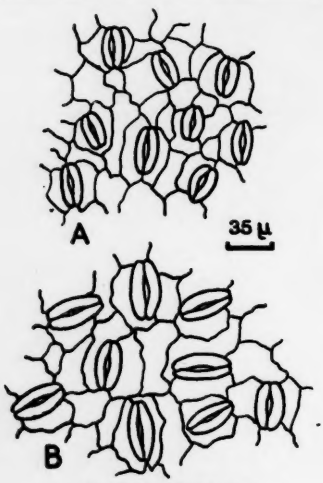
Figure 20

The leaves of the tetraploid plant (*B*) have larger lobes which are suddenly constricted at the tip whereas the controls (*A*) have narrower lobes and are slender to the tip. The irregularities in the middle of the lobes are more marked in the leaves of tetraploid plants. (Reduced about 1/8). In cross section, the difference between the leaves of plants containing 36 and 72 chromosomes is very marked. *A'* shows a section of a leaf of a plant with 36 chromosomes and *B'* of one with 72 chromosomes. (× 150.)

survive: six of these were in the group treated with 0.5% colchicine, and seven in the other (1%) group.

Chromosome Duplication

Some of the treated plants soon showed a marked difference in respect to the size of the stomata. In some of these plants the average major diameter of the stomata was 40μ, whereas com-



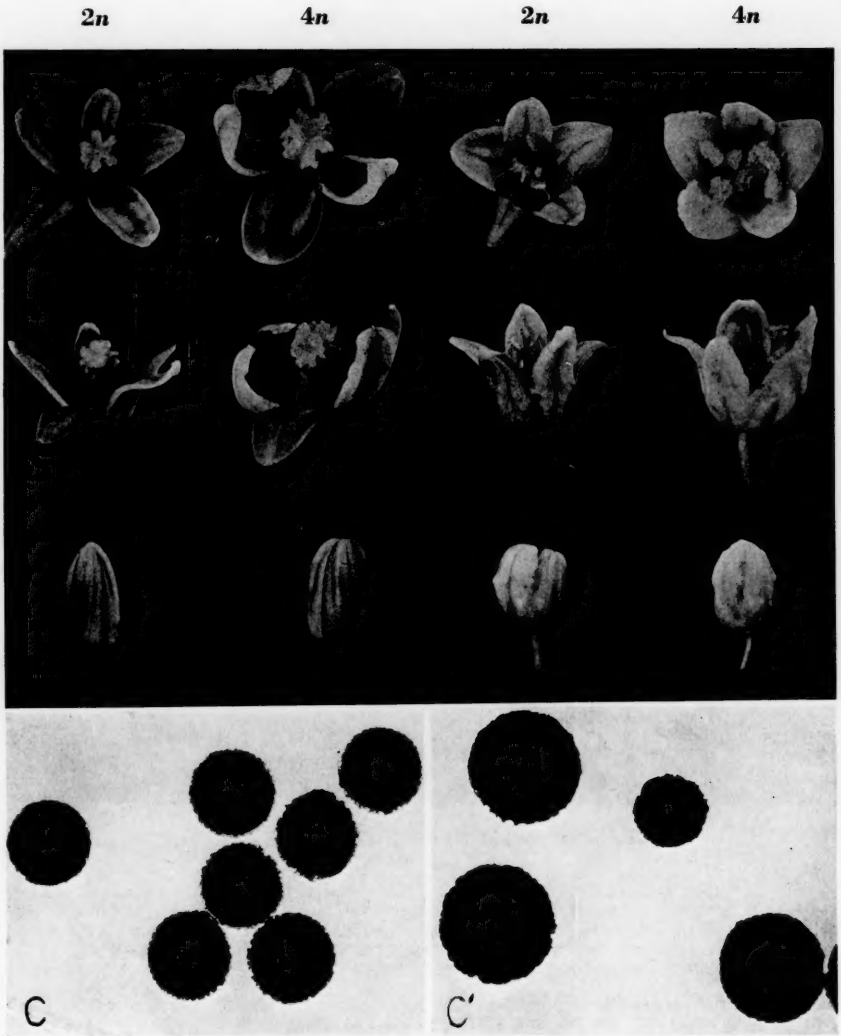
LARGER STOMATA

Figure 21

The stomata of a tetraploid plant (*B*) are larger than those of the diploid control (*A*). A detailed statistical analysis showed that the plants treated by colchicine formed two groups according to the mean length of the stomata. Statistics of measurements of control and tetraploid plants are given below:

Major diameter of stomata

Control CA/1	Treated Plant 1/5
n = 180	n = 180
v = 28,1	v = 40,0
σ = ±3.2	σ = ±6.2
σ_v = ±0.2	σ_v = ±0.5
σ% = ±11%	σ% = ±15%



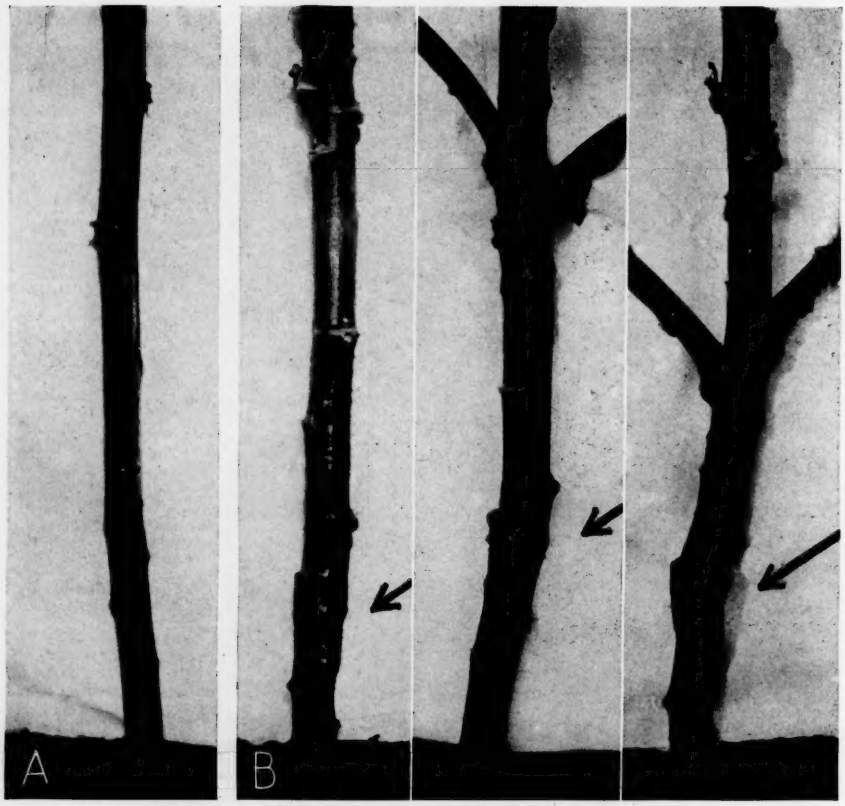
MALE AND FEMALE FLOWERS

Figure 22

In *A* are shown various aspects of the female flowers from the diploid (*2n*) and tetraploid (*4n*) plants. *B* shows comparable male flowers. The flowers of the tetraploid plants are larger than those of the diploids (× 1.5). *C* and *C'* show the difference in size of the pollen grains of a normal and of a tetraploid plant respectively. (× 200.)

parable stomata of the control plants averaged 28μ, as illustrated in Figure 21. By means of a detailed statistical analysis the treated plants were separated into two groups, one with an average of the major diameter of the stomata similar to that of the control and the other with an average of the major diameter of 40μ. The details of this analysis are included in a preliminary publication.[4]

Some plants flowered in six months, thus allowing a more detailed compari-



JUNCTION OF DIPLOID AND TETRAPLOID TISSUE

Figure 23

Plants treated with colchicine and having a duplicated tetraploid number of chromosomes, possess only an aerial tetraploid part, because the treatment was applied to the apex of a principal shoot. *A* shows a stem of a control and *B* the three main shoots of altered plants. An arrow indicates the place where the transition from diploid to tetraploid tissue occurs.

son among the treated and control plants with regard to nearly all characters.

The general appearance of a treated plant, in contrast to that of a control can be seen in Figure 19.

The leaves of the treated plants with an average stomata length of 40μ have larger lobes which are suddenly constricted at the tip (Figure 20*B*) in contrast to the leaves of the controls which lobes were narrower throughout. (Figure 20*A*.) When irregularities occur in the middle of the lobes, they are much more marked in the leaves of the altered plants (Figure 20*B*). The thickness of the leaves of treated plants and those of the control plants are also different, as shown by Figure 20 *A'-B'*.

Figure 22*A* shows a female flower of a plant altered by the treatment. All its parts such as petals, ovary, stigma and petiole are larger in comparison with the same parts of the flower of a control shown at the left.

The male flower of an altered plant shown in Figure 22*B* has larger petals

DEFORMED PLANT
Figure 24

A highly altered plant produced by treatment. Its number of chromosomes is not determined but it probably is a more complex polyploid form or a chimera.

and anthers than in a normal plant shown there. The lateral view of the two flowers shows that the difference consists principally in the enlargement of the petals.

The size of the pollen grain of the control is smaller than that of the pollen of an altered plant as is shown in Figure 22*C*. The former are also much more uniform.

The number of chromosomes of the normal diploid plants is 36 while plants with altered morphological characters described above have the tetraploid number of 72. The chromosomes are illustrated in Figure 19*B*. A more detailed cytological analysis of the plants is in progress and besides tetraploid plants having 72 chromosomes, one plant with 144 chromosomes ($8n$) was also found.

The differences described above could be observed in six-months-old plants. The characteristics of the roots, the part of economic value of the plants, can only be studied successfully later. The treatment was made in the terminal part of the shoots and the roots of the treated plants thus remained diploids. After its first vegetative cycle, about a year, these plants showed an interaction of the tetraploid aerial part and the diploid underground base. This interaction can be observed in Figure 19*C*. Both in the control plants shown in Figure 19*C* and in the plants with a duplicated number of chromosomes shown in 19*C'*, the roots are deformed owing to the fact that they remained too long in pots during the first stages of their development. In spite of this, the production of the roots in both cases was more or less satisfactory, and in the treated plants, having a subterranean diploid base and an aerial tetraploid part, the interaction between these two parts was such as to permit a production of well developed roots, though they are thinner than the roots produced by the control plants. In Figure 23*B* the transition zone of the altered and unaltered parts of the treated plants can be seen, in comparison with a control plant.

The plants obtained by the treatment will only give cutings which will be completely polyploid after its first cycle has been concluded. The commercial production may thus be analyzed only after another nine months or preferably after two more vegetative cycles, that is 18 months. Commercial plants are cultivated especially on this last basis because it gives a production almost double and with less cultivation than is necessary during the first cycle.

The octoploid plant is so slow in development that a detailed analysis has not yet been possible. In general appearance it resembles very much the tetraploid except for the retardation of growth.

Among the plants treated was one whose appearance was extremely altered as is shown in Figure 24, and which in comparison with the other plants made

a very poor growth. Its leaves are very wrinkled and irregular and in general the plant has a very slow development. The general appearance indicates that we may have to deal here with a more complex polyploid form. On another plant which was treated by colchicine and kept in a cemented plant-bed, one branch appeared with leaves resembling those of the plant mentioned above. This branch has to be considered as a chimera but since its development could not compete with that of the rest of the plant, it died some time after its appearance.

It is not necessary to dwell upon the importance which the polyploid forms of cassava may have in the production of improved varieties. Although the flowers of the plants were badly injured by insects we have attempted to cross the different polyploid forms obtained with individuals of a species very similar to *M. utilissima* and with the same diploid number of chromosomes, found in the neighborhood of another city of the State of S. Paulo.

Literature Cited

1. Blakeslee, A. F., and A. G. Avery. Methods of inducing doubling of chromosomes in plants by treatment with colchicine. *Jour. Hered.* 28:393-411. 1937.

2. Graner, E. A. Contribuição para o estudo citologico da mandioca. Publication of the Escola Superior de Agricultura "Luiz de Queiroz." Piracicaba, S. Paulo, Brazil. 1935.

3. ————————. Chimera chromosomica na mandioca. Publication of the Escola Superior de Agricultura "Luiz de Queiroz." Piracicaba, S. Paulo, Brazil. 1935.

4. ————————. Tratamento de mandioca pela colchicina. I-Nota preliminar sobre poliploidia indicada pela diferença de tamanho dos estomatos. *Jornal de Agronomia* Vol. 3:83-98. 1940.

The Tongue-Tied Twin

The findings of this study seem to warrent the following general conclusions:

1. Only children are definitely superior to children with siblings in every phase of linguistic skill.
2. Singletons with siblings are in turn somewhat superior to twins.
3. Twins from the upper occupational groups by 9½ years have practically overcome their language handicap, but twins from the lower occupational groups have made relatively little progress. This finding necessitates careful control of the socio-economic factor in subsequent studies dealing with language development in twins.
4. Twins of the ages studied in this investigation are especially retarded in perfection of articulation. The inferiority is marked during the kindergarten period, particularly in twins from the lower occupational groups.
5. At least during the kindergarten year, the child's mastery of articulation is closely related to other phases of language development. There are indications in the data that faulty articulation, if unduly prolonged, may become a major handicap preventing both adequate command of language and wholesome development of the personality. — Davis, Edith A., *Linguistic Skill In Twins, Singletons with Siblings, and Only Children,* University of Minnesota Press.

Flesh and Bone Genes in the Fowl

Genetic Studies of Skeletal Dimensions and Their Relation to Body Weight and Egg Production in the Domestic Fowl (Gallus domesticus), J. H. Quisenberry, E. Roberts, and L. E. Card. (Univ. Ill.). *(Poultry Sci., 20 (1941), No. 2, pp. 104-120, figs. 2).*—In the F_2 generation from Dark Cornish × White Leghorn fowls a definite significant correlation was found between low egg production, large egg size, and diameter of the tibia, although these characteristics were not significantly correlated in the parental breeds. Measurements of the length, diameter, and weight of several long bones and other portions of the skeletal structures of the F_2 birds were highly correlated with mature weights (0.64 to 0.73). Correlations between the measurements and body weight in the parental breeds and F_2S were significant and high. The reciprocal F_1 crosses differed so significantly in egg production (mean with Leghorn sire, 163.67 and with Cornish sire, 140.60) as to suggest the influence of a sex-linked factor for broodiness carried by the Cornish parents (E. S. R., 70, p. 605). Even with the weights taken at 2-week intervals there were no significant differences up to from 8 to 12 weeks between the two parental breeds, but after 16 weeks striking differences in growth were apparent.—*Expt. Sta. Record.*

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